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Final Report

**Remedial
Investigation Report
Crab Orchard National
Wildlife Refuge**

U.S. Fish and Wildlife Service
U.S. Department of the Interior
Marion, Illinois
and
Sangamo Weston, Inc.
Atlanta, Georgia

August 1988



O'BRIEN & GERE

REMEDIAL INVESTIGATION REPORT**VOLUME I: REPORT****CRAB ORCHARD NATIONAL WILDLIFE REFUGE**
Remedial Investigation/Feasibility Study**U. S. FISH AND WILDLIFE SERVICE**
U. S. DEPARTMENT OF INTERIOR
MARION, ILLINOIS**and****SANGAMO WESTON, INC.****ATLANTA, GEORGIA****AUGUST, 1988****O'BRIEN & GERE ENGINEERS, INC.**
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EXECUTIVE SUMMARY

The Crab Orchard National Wildlife Refuge ("the Refuge"), Marion, Illinois, is owned by the U.S. government and is currently administered by the U.S. Fish and Wildlife Service (FWS). This area was previously administered by the Department of Defense (DOD). During the DOD administration, a number of wartime industries operated on the eastern portion of the refuge in the early 1940s. These industries were primarily involved with the manufacture of munitions, although non-military industries also operated. A few industries continue to operate at the Refuge under the FWS administration. Although the western portion of the Refuge is a popular recreation area, public access is generally limited to authorized personnel on the eastern portion. A site map showing the Refuge boundaries is included as Figure 1-3.

Several investigations performed in the last decade have indicated the presence of polychlorinated biphenyls (PCBs), lead, and arsenic in soils within the eastern portion of the Refuge. The objectives of this Remedial Investigation (RI) are to define the nature and extent of contamination at the Refuge, and to assess the potential impacts from these contaminants to human health, wildlife, and the environment. The RI assessments will form the basis for a Feasibility Study (FS) to be completed following the submission of the RI Report. Follow-up remedial actions, where needed, will be evaluated as part of the FS.

The Refuge consists of 35,000 acres of forested land, pine plantations, and cultivated land. There is a large wildlife population, including deer, rabbits, bald eagles, ducks, and quail. In addition, Crab Orchard Lake provides sports fishermen with largemouth bass, catfish, sunfish, and crappie.

The RI addressed thirty-three sites at the Refuge, including two 'control' or background sites. A majority of the investigated sites are located on or near tributaries or drainage-ways that discharge into Crab Orchard Lake. Additional sites are investigated within the eastern area of the Refuge where disposal activities were known or believed to have occurred, based on the records provided by the Refuge Manager or the recollection of Industrial or Refuge employees. Crab Orchard Lake is also evaluated as a study site in this investigation, since it is currently used as a drinking water supply for the Refuge, industrial tenants, and a nearby penitentiary. The lake has also been used once or twice within the past ten years as an auxiliary intake for the City of Marion; however, the city backup supply intake is now drawn from Herrin Lake.

Field work for the RI was performed in two phases. The Phase I investigation consisted of: geophysical surveys; hydrogeological investigations; the collection of soil, surface water, and sediment samples; and the analytical screening of these samples. The objective was to assess the presence and the potential for migration of contaminants. Where possible, analytical parameters for the Phase I screening were selected based on the results of previous investigations and the knowledge of historical site uses; otherwise, broad analytical scans were employed in the analyses.

The Phase II program consisted of additional sampling and analysis to supplement and verify the Phase I data and to better define the extent of contamination at sites where contaminants had been detected during Phase I. Ground water and fish samples were also analyzed as part of Phase II. The analytical parameters for the Phase II analyses were generally selected based on the results of the Phase I characterization, using lower limits of detection or more specific analytical protocols to further define the areas of contamination.

Risk assessments were performed to evaluate the environmental effects of the detected contaminants. The assessment of environmental effects includes a qualitative assessment to determine the existence of a contaminant source, a viable transport route, and a potential receptor at risk of exposure. If all three components are identified, a quantitative assessment is performed to evaluate the potential for, and the significance of such exposures to human or wildlife receptors. Where applicable or relevant, the concentrations of contaminants are compared to state and federal criteria or standards. See Table ES-1.

Table ES-2 provides a summary of the actions which are recommended for each study site evaluated in the RI. Of the thirty three (33) sites, seven (7) sites have been suggested for further evaluation in the FS, including Sites 15, 17, 22, 28, 29, 32, and 33. Sites 3, 4 and 19 have been recommended for further evaluation by the Department of Defense, since the preliminary screening of these sites in Phase I of the RI did not allow a definitive recommendation regarding the traces of nitrosamines residues detected at those sites. Fifteen (15) sites (including the two control sites) have been determined to pose insignificant or negligible risk under current conditions, and, on this basis, are concluded to require no further evaluation in the FS. The remaining eight (8) sites consist of waterways downstream of active industrial operations; these sites have been recommended for continuing periodic monitoring to ensure that water quality does not deviate from the baseline conditions observed during the RI. Attachment 1 details the following proposed monitoring programs:

- Sites 10 and 11 (Waterworks North Drainage and P Area Southeast Drainage Channels), might be monitored quarterly for cyanide, iron, magnesium, manganese, mercury, and phthalates in water; full scans of volatile/semi-volatile compounds will be monitored annually;

- Site 14, Solvent Storage, might be monitored quarterly for volatiles (methylene chloride, acetone, chloroform), and phthalates in water;
- Site 16, Area 7 Industrial Site Ditch, might be monitored quarterly for volatile and semi-volatile organics (chloroform, carbon tetrachloride, polyaromatic hydrocarbons), and pesticides (aldrin, dieldrin) in water;
- Sites 25, 26, and 27 along Crab Orchard Creek might be monitored quarterly for cyanide, magnesium, manganese, TOC, and TOX in water; and,
- Site 34, Crab Orchard Lake, might be monitored for pesticides/PCBs, and arsenic in water.

A site-by-site summary of the RI and risk assessment results follows:

Control Sites: Background concentrations for all analytical parameters surveyed in this investigation are defined by the analyses of soil and groundwater matrices at two control sites, Sites 30 and 31, the Refuge Control and Munitions Control sites. These sites are known to be removed from previous and present potential sources of contamination. The constituent concentrations detected at the investigated sites were compared to those detected at the control sites.

Site 3, Area 11 South Field: This site is an area located adjacent to an old railroad spur that served abandoned explosives and nitrogen fertilizer manufacturing areas. Phase I analyses of three composite surface soils (from the north, south and east banks) and two composite sediments (one from the marsh and one from the lower stream) indicated traces of HMX (Octahydro-1,3, 5,7-tetranitro-1,3,5,7-tetrazocine) and RDX (Hexahydro-1,3, 5-trinitro-s-triazine), as well as elevated lead and zinc.

The one soil sample screened for organics indicated the presence of N-nitrosodiphenylamine and 2,6-dinitrotoluene.

The Refuge Manager indicated that the DOD will be responsible for further evaluation of this site.

Site 4, Area 11 North Field: This field appears to have been the site of a two to three acre impoundment; the area is dry except for small intermittent streams or marsh areas bordering the east and west boundaries. RDX or magnesium may have been stored underwater here, or the site may have been used for experimental detonations of explosives. Phase I analyses of one composite surface soil and one composite sediment sample (from the marsh) indicated elevated levels of nitrate and 2,4-dinitrotoluene in soil. Heavy metal concentrations were consistent with concentrations detected at the control sites with the exception of sodium. The sediment was resampled for full CLP organics screening and indicated the presence of N-nitrosodimethylamine.

The Refuge Manager indicated that the DOD will be responsible for further evaluation of this site.

Site 5, Area 11 Acid Pond: Site 5 is a diked impoundment which received drainage from the Area 11 process buildings. As discussed above (Sites 3 and 4), Area 11 was previously used for explosives and nitrogen manufacturing and for munitions loading. The pond discharges to a small stream. The Refuge Manager recalled verbal accounts that an area downstream of the pond became devoid of vegetation due to an accidental release of acidic water from the pond. Phase I analyses of one surface water, one sediment, and one soil sample indicated that the acidic residuals had been neutralized or dissipated. The sediment and soil contained chromium, but none was detected in the water. The sediment sample

screened for organics indicated the presence of N-nitrosodimethylamine and di-n-octyl phthalate, although phthalates were also detected at the control sites. One surface water was analyzed and found to contain iron and manganese above the Illinois and Federal secondary (aesthetic-based) water standards. No Phase II sampling was conducted because an evaluation of the data did not warrant further investigation. An evaluation of these data showed that contaminant levels do not represent a concern or risk of exposure to humans or to wildlife.

Site 7, D Area SE Drainage Channel: This site includes a segment of the drainage channel leading from the active industrial facilities in the Olin D Area. The drainage channel eventually discharges to Crab Orchard Lake. Phase I analyses of one composite sediment showed that magnesium was the only constituent that was elevated above the levels detected at the control sites. One surface water sample was analyzed and found to contain iron and manganese above the Illinois Public Water Supply and Federal MCL secondary standards. The concentration of total organic halides (TOX) in the water sample was slightly elevated, but volatile organics were not detected. Phase II analyses were limited to the confirmation of the Phase I mercury level, due to poor calibration data in the Phase I data point, and showed levels similar to those found at the control sites.

No contaminants were found to represent a concern or risk of exposure, thus no further evaluation appears warranted. A monitoring plan for waters downgradient of this site is proposed, however (see Site 10), due to active industrial activities within the D and P areas.

Site 7A, D Area North Lawn: Barrels of chemicals were reportedly dumped on a knoll within this lawn located northwest of the Olin D Area Complex. No evidence of a knoll remains; only a number of depressions

with brown patches were noted. Phase I analyses of six composite soils sampled up to a depth of 3 ft and along three field transects indicated that concentrations were consistent with those detected at the control sites. Geophysical surveys performed at this site did not reveal any unusual subsurface metallic objects or free liquids. One soil composite was resampled for full organics analyses, in which di-n-octylphthalate was detected, but this compound was also found at the control sites and possibly as a lab contaminant also. In Phase II, the same locations were resampled to a depth of 1 ft to confirm the Phase I mercury concentrations.

The evaluation of environmental effects determined that the low contaminant levels would not represent a concern or risk of exposure. No further evaluation of this site is recommended.

Site 8, D Area Southwest Drainage Channel: Site 8 includes a parallel but opposite branch to the Site 7 Drainage Channel; both channels lead from the Olin D Area and discharge into Crab Orchard Lake at Site 10. Phase I analyses of one surface water and one sediment sample indicated that the water met the Illinois and Federal standards for all parameters except manganese which was slightly above the aesthetic-based standard. The water contained elevated TOX, but no volatile organics were detected. The sediment contained concentrations consistent with those detected at the control sites with the exception of magnesium.

No Phase II sampling was conducted because the levels detected in the Phase I screening did not justify the need for additional investigation. Contaminant levels were not considered to represent a concern or risk of exposure. No further evaluation of this site is recommended, with the

exception of periodic monitoring of downgradient waters where these drainage channels converge.

Site 9, P Area Northwest Drainage Channel: This site is located downgradient of Sites 7 and 8 channels; leading drainage from the Olin P Area (currently an active industrial area) and discharging into Crab Orchard Lake. Phase I analyses of one composite surface water and one composite sediment sample detected low levels of cyanide and mercury in sediment, but neither parameter was detected in the surface water. The water sample contained a high TOX concentration but no volatile organics were detected. Cyanide levels in sediment were reanalyzed in Phase II survey to confirm the Phase I level; the results showed that the cyanide concentration was below the detection level of 5 mg/kg.

Contaminant levels were not considered to represent a concern or risk of exposure. No further evaluation appears warranted, although continuing industrial activities in the area would suggest routine monitoring of these waterways (see Site 10).

Site 10, Waterworks North Drainage Channel: Site 10 includes the bay where various drainage ways leading from Areas D and P converge prior to entering Crab Orchard Lake. Phase I analyses of one composite surface water and one composite sediment sample indicated the presence of phthalate esters and cyanide in the sediments, but not in the water. The detection of phthalates may be overstated since these compounds may have been present as lab contaminants and were also detected at the control site. The sediment was sampled twice, first for a general screening analyses and then to perform a full CLP organics scan. The water contained iron and manganese at levels which exceeded the secondary standards for Illinois and Federal Drinking Waters. Cyanide concentrations

were below the detection limit of 5 mg/kg in the Phase II resampling and analyses of five grab sediment samples and one composite surface water sample, but phthalates were again detected in the sediments. Phthalates were also detected as a lab contaminant.

Contaminant levels were not considered to present a potential risk to humans, wildlife, or the environment. However, due to the site's proximity to the Refuge Waterworks intake, and continuation of industrial activities in this area, it is recommended that periodic monitoring be conducted as proposed in Attachment 1.

Site 11, P Area Southeast Drainage Channel: Site 11 Drainage Channel collects surface water from upstream Areas D and P, and runs parallel to the branch which conforms Site 10. Site 11 consists of the bay area formed as these channels discharge to Crab Orchard Lake. Phase I analyses of one composite surface water and two composite sediment samples indicated that the water contained HMX as well as an elevated TOX concentration. Manganese was detected in the water slightly above the Federal MCL. A second sediment composite was taken for full CLP organics: the results showed that the concentrations of all parameters were consistent with those detected at the control sites with the exception of mercury. In Phase II, one composite water sample and one composite sediment sample were resampled and analyzed for cyanide and mercury. Neither parameter was detectable in the water, and mercury levels in sediment were not atypical of the levels usually found in soils.

No contaminants were detected that might pose a threat to human health, wildlife or the environment, based on the risk evaluation performed for this site. No evaluation of remedial alternatives is considered,

although a follow-up monitoring program (see Attachment 1) might be instituted to monitor active industrial activities in the area.

Site 11A, P Area North: This site includes an abandoned L-shaped covered walkway which terminates in loading areas. Chemicals may have been dumped outside of these buildings. Phase I analyses of eight composite soil and sediment samples from various locations throughout the site indicated that magnesium levels in samples outside three doorways were generally an order of magnitude greater than the levels found at the control sites or elsewhere at this site. A maximum lead concentration of 130 mg/kg was measured in one sample while all other samples were similar to the control sites (about an order of magnitude lower). One soil sample screened for full CLP organics indicated the presence of di-n-octyl phthalate; it is noted that this compound was also detected at the control sites, however. Mercury analyses were repeated in Phase II showing that this parameter is not present at levels to constitute a concern.

The concentrations of site indicator contaminants were not found to constitute a risk of exposure. No further evaluation of this site is recommended.

Site 12, Area 14 Impoundment: This site is a circular dry impoundment of approximately 100 ft diameter which is no longer used. Munitions loading activities took place in Area 14 in the past; currently, this general area is occupied by Diagraph Bradley for the manufacture of printing inks and stencils. Phase I analyses of one composite soil and one composite sediment sample showed relatively high organic indicators such as TOC and FID screen. The sediment was resampled for a full priority pollutant analysis, but only N-nitrosodiphenylamine and trace microgram

levels of various base/neutral extractable compounds were detected. No Phase II sampling was warranted for evaluation of the site.

The evaluation of environmental effects for this site concluded that the potential risk levels are within the range considered acceptable for protection of human health and wildlife species. No further evaluation of this site is recommended, and this site will not be addressed in the FS.

Site 13, Area 14 Change House: Site 13 is currently an open field covered with tall grasses, but was previously the site of a building where munitions workers changed their clothing. A geophysical survey of the area and analyses of six composite surface soil samples indicated that all concentrations were consistent with those detected at the control sites. No Phase II sampling was needed.

Based on the known history of the site and the results of the site characterization which did not show any contaminants of concern, the site was not considered to represent a risk of exposure. No further evaluation of this site is recommended.

Site 14, Area 14 Solvent Storage Ditch: This site includes a portion of a small, intermittent drainage ditch adjacent to a manufacturing area where solvents are handled. Phase I analyses of two composite surface water samples indicated that chloroform was present in both samples at levels above the Ambient Water Quality Criteria (AWQC) for human health, even though these were orders of magnitude below the same criteria for aquatic life protection. One of the sediments was resampled and analyzed for full CLP organics, and was found to contain acetone, methylene chloride and low traces of N-nitrosodimethylamine. Acetone levels may have resulted due to contamination of the sampling equipment, since an acetone rinse was applied to avoid cross-contamination. Phase II results confirmed

the presence of chloroform and methylene chloride in the water, although methylene chloride was also detected in the blanks. The volatiles were again measured above the AWQC for human health protection. The sediment sample analyzed in Phase II contained methylene chloride and phthalates, but the phthalates were also present as a lab contaminant.

The site-specific risk assessment evaluated the levels of all parameters detected, but focussed on methylene chloride due to its persistence in the stream sediments. A recommended monitoring program was developed to ensure that contaminant levels in water do not pose a risk of exposure to humans or terrestrial or aquatic wildlife. In addition, improved housekeeping practices were recommended for the handling of solvents in the area. In its current condition, the site was not considered a concern for protection of human health or wildlife. Site 14 will not be evaluated in the FS.

Site 15, Area 7 Plating Pond: The Area 7 pond reportedly received plating wastewater from nearby, previously active industrial operations; an inlet pipe was located but it appears the pond has no outlet. Phase I analyses of one surface water composite and one sediment composite indicated that the water met Illinois and Federal MCL standards for all parameters except iron. The sediment contained approximately 500 mg/kg chromium; in addition, a full CLP organics screening indicated the presence of the pesticide alpha-endosulfan. Phase II investigations consisted of one ground water sample as well as analyses of one composite sediment sample for extractable chromium. Unfiltered ground water contained arsenic, lead, and chromium, none of which were detected in the filtered ground water. No volatiles or pesticides were detected in the

water. The Extraction Procedure Toxicity analysis showed that the pond sediments are non-hazardous.

Although the levels of parameters were not considered to represent a concern or risk of exposure, it is recommended that the site be considered in the FS to evaluate alternatives for pond closure.

Site 16, Area 7 Industrial Site: Area 7 consists of a complex of 33 buildings which have been used for a variety of industrial purposes during the past 40 years. Most of these buildings are currently used for dry warehousing purposes, but three structures are occupied by Pennzoil for waste oil recovery and recycling. Black oily spots were noted around some of these buildings. Site 16 consists of the drainage ditch which traverses the Area 7 complex from south to north.

Phase I analyses of two surface water composites indicated that the surface water met the Illinois and Federal MCL standards for all parameters except manganese. However, one of the water samples contained traces of chloroform and carbon tetrachloride at levels above the AWQC for human health, although not above the same criteria for aquatic life protection. Three composite sediment samples were also taken from the ditch and nine surface soil composites were taken from areas where black stains were noted. Trace amounts of base/neutral extractable compounds were detected in two of the soil samples and one sediment sample. All other concentrations were consistent with those detected at the control sites. Phase II sampling involved the collection of one surface water composite and one sediment composite from the ditch downstream from the Phase I samples. All parameters analyzed in these downgradient samples were within the Federal and State standards. Traces of chloroform, chlorobenzene, and phthalates were detected in the sediment; however, the

levels present did not present a concern for toxicity or were also present in the lab blanks (phthalates).

The microgram levels of volatile and semi-volatile constituents detected in the ditch and/or in isolated locations in the building complex were not considered to present a potential risk to humans, wildlife, or the environment. Periodic monitoring of the ditch water could be conducted (see Attachment 1) to monitor the oil recycling operation and prevent offsite transport of potential contaminants. No additional study is recommended other than routine monitoring.

Site 17, Job Corps Landfill: This site includes both an inactive, abandoned landfill, and an adjacent 10-acre pond. Phase I analyses of seven surface areal composite soils indicated the widespread presence of PCBs and lead; in addition, cadmium and trace parts per million of the explosive tetryl were detected in some of the samples. Phase II of the survey included 0-3 ft depth soil cores spaced in a grid pattern throughout the landfill, installation and sampling of five groundwater monitoring wells, six sediment samples and two composite water samples from the pond. The Phase II analyses confirmed the presence of PCBs and lead in all surface soil and sediment samples up to a depth of 1 ft. Deeper soil cores obtained from the landfill did not show elevated levels of contaminants. A depth profile of contaminants within the pond sediment has not been characterized, although, based on the distribution of contaminants in the landfill, it would be expected that PCBs and lead levels in the pond may also be limited to the surface of the basin. Total chromium (in groundwater) and PCBs (in groundwater and in the pond) were above the regulatory criteria for some water samples. The PCB concentrations measured in the pond water were above the AWQC for

chronic exposure to both aquatic species and humans, but well below the level established for acute exposure (maximum concentration). Total lead was also above the Federal MCL for one well water; chloroform and pentachlorophenol were detected above the AWQC for two ground water samples.

Additional characterization of the pond and of the leachability of metals within the soils of the landfill is recommended. A detailed wildlife and human risk assessment was performed to establish that the exposed waste contaminants must be remediated, to prevent exposure to terrestrial mammals or occasional site trespassers. This site is recommended for further evaluation in the FS.

Site 18, Area 13 Loading Platform: Site 18 consists of a long concrete pad (roughly 235 ft by 10 ft) and its immediate surroundings. The general area around the site contains approximately 85 bunkers that were originally used to store bombs; some bunkers continue to be used for storage of explosives or agricultural crops. Area 13 was served by a rail spur which runs adjacent to the loading platform.

Phase I analyses indicated traces (below 2 mg/kg) of the explosive tetryl in two of the four composite soil samples collected around the perimeter of the platform. The north and south composites consisted of 20 grabs each in order to provide a representative sample. Magnesium was detected above the levels found at the control sites in all four composites. One sample screened for CLP organics indicated the presence of di-n-octyl phthalate, acetone and methylene chloride, although these compounds were also present in the lab blanks. Phase II sampling was not conducted. The results of the site characterization did not show contaminants at levels

which would be of concern or that might present a risk to the environment. No further evaluation is recommended at Site 18.

Site 19, Area 13 Bunker 1-3: Site 19 includes the area around one bunker in Area 13. The site was selected on the basis of verbal accounts that chemicals were spilled in the field adjacent to this bunker. Phase I screening analyses of five areal soil composites (one from each side of the bunker as well as one sample from one area of brown vegetation in the adjacent field) detected N-nitrosodimethylamine, at a level higher than at any other site on the Refuge. The Phase II investigation involved reanalysis of one soil sample for mercury; the results showed mercury levels similar to the levels at the control sites.

The results from the qualitative and quantitative risk evaluation indicated that, although the potential risks to humans were well within the acceptable bounds for health protection, the worst case exposure estimate for wildlife might affect sensitive local species. It is recommended that additional characterization efforts be conducted at this site prior to evaluation of remedial options, if needed.

Site-20, D Area South Drainage Channel: This drainage channel is located within the Olin D Area south of Site 7, originating at an abandoned building and running east past the fenced complex. Phase I analyses of one areal sediment (composite of four grabs) indicated the presence of low levels of cyanide and mercury. The sediment was also screened for organics and contained di-n-octyl phthalate, bis (2-ethylhexyl) phthalate, and N-nitrosodimethylamine; however, the levels detected were not considered to represent a threat to humans or to wildlife on the basis of the evaluations of similar levels at other sites. Phthalates are commonly

detected due to contamination of laboratory blanks; di-n-octyl phthalate was also detected at the control sites.

No Phase II sampling was conducted. No further evaluation of this site is recommended, although periodic monitoring has been recommended for Sites 10 and 11 which are waterways downgradient from this site.

Site 21, Southeast Corner Field: This site is a fenced field thought to be the site of an old landfill due to the presence of concrete rubble near one end. Geophysical surveys performed in Phase I did not reveal any unusual subsurface metallic debris. Four composite surface soils were collected along four north-south transects. The soil sampled from Transect 1 was resampled for full CLP organics analyses. Magnesium levels were roughly one order of magnitude higher than at the control sites. The one sample screened for organics indicated the presence of trace part per billion (ppb) levels of base/neutral extractable compounds, including N-nitrosodiphenylamine. Phase II investigations were limited to resampling of one soil sample for mercury analysis, but the results did not show elevated levels.

No further evaluation of this site is recommended. Site 21 will not be addressed in the FS.

Site 22, Old Refuge Shop: The Refuge Shop, located behind the location of the Old Refuge Headquarters, was previously the location where pine wood poles were treated using pentachlorophenol preservative. A small drainage pool exists downgradient of the site. Site 22 includes this pool and the drainage channel which extends through the woods to Crab Orchard Lake. Phase I analyses consisted of one grab surface water and one composite sediment sample from the drainage ditch. The sediment was later resampled for a full CLP organics scan. While the water sample met

Illinois Public Water Supply and Federal MCL standards, the sediment contained several contaminants, including cyanide, cadmium and chromium. Phase II analyses of five surface sediments from the ditch (spaced between the Shop and the lake) indicated extractable cadmium concentrations that exceeded the RCRA criterion for hazardous waste. Trace semi-volatile compounds including 2-methylnaphthalene, bis (2-ethylhexyl) phthalate, fluoranthene, pyrene and others, were also detected in the sediment. One ground water sample was collected and found to contain cadmium and cyanide concentrations above the Federal MCL and State water standards.

Based on an evaluation of the site characterization data and the potential effects these may pose to humans, wildlife, or the environment, it is recommended that remedial measures for this site be addressed in the FS.

Site 24, Pepsi-West Drainage: Site 24 consists of a small drainage ditch which receives run-off from a nearby active bottling company; the site is not located within the Refuge. Phase I analyses of one surface water and one sediment sample indicated slightly elevated TOX in the water, although no organics were detected. The sediment contained acetone and methylene chloride, but these compounds were also present in the lab blank. Phase II reanalysis of mercury in the sediment showed levels slightly above the concentration detected at the control sites but not outside the range for typical concentrations of mercury in soil.

The concentrations of parameters detected at this site were not found to represent a concern for protection of human health, wildlife, or the environment. No further evaluation appears warranted; therefore, this site will not be considered in the FS.

Site 25, Crab Orchard Creek at Marion Landfill: This site consists of Crab Orchard Creek upstream and downstream of a former municipal landfill, as well as an adjacent pond. Phase I analyses of one composite surface water upstream and one downstream location detected magnesium, manganese, TOC, TOX, and cyanide, with concentrations increasing from the upstream to the downstream locations. Manganese and iron were the only contaminants that exceeded Federal MCL or Illinois Public Water Supply standards. Upstream and downstream sediment composites were also collected; the downstream sediment was also resampled for full CLP organics analysis. The downstream sediment contained elevated concentrations of TOC and cyanide, while magnesium levels for both locations were consistent with those detected at the control sites. Composite sediment and water samples from the pond also showed the presence of magnesium and cyanide in sediment. Manganese and iron concentrations were above the Federal MCL and State standards in the pond water.

Phase II re-analysis of one upstream creek sediment sample indicated a cyanide concentration similar to that detected during Phase I and similar to the concentrations detected at the control sites. The excursions noted for manganese and iron in creek and pond water samples do not represent a health hazard, since these parameters are regulated based on aesthetic concerns. The levels of constituents detected in sediments were not perceived as a concern, due to the low levels present and the limited exposure possible for potential receptors.

Follow up monitoring studies for Crab Orchard Creek water are recommended, to ensure the continued protection of animals and humans.

Attachment 1 details a proposed monitoring plan. This site will not be considered in the FS.

Site 26, Crab Orchard Creek Below Marion STP: Two sediment and two water composite samples were collected from Crab Orchard Creek downstream of the Marion Sewage Treatment Plant, spaced approximately 2,000 ft apart. Phase I analyses indicated that the surface water sample downstream contained about twice the TOX concentration (49 ug/l versus 125 ug/l downstream), and exceeded the Federal MCL and Illinois Standards for iron and manganese. Manganese was above the standard in the upstream sample as well. Chloroform was detected in the water samples at levels above the corresponding AWQC for protection of human health, but not over the criterion for aquatic life protection. Sediment concentrations were consistent with those detected at the control sites.

The types of contaminants and the levels detected in sediment and water were evaluated but were not found to represent a concern or risk of exposure. However, as a drainage route discharging to Crab Orchard Lake, monitoring of the creek water is suggested. Attachment 1 details a proposed monitoring program. This site will not be considered in the FS.

Site 27, Crab Orchard Creek Below I-57 Dredge Area: Dredging of the stream bed of Crab Orchard Creek was conducted in the area downstream of Route 57. Site 27 consists of one composite water sample and one composite sediment sample collected near the dredged area. Phase I analyses showed most parameters were below the levels detected at upstream Site 26. The surface water contained iron and manganese above the Federal and State standards. The concentrations detected in the sediment were consistent with those detected at the control sites. No Phase II sampling was conducted.

The parameters detected were not present at levels which would present a risk to humans, wildlife or the environment; therefore, this site will not be considered in the FS. However, further evaluation in terms of monitoring of surface waters is suggested. Attachment 1 details a proposed monitoring program.

Site 28, Water Tower Landfill: This site is a former landfill that may have been used as a disposal area by industries operating at the Refuge. Phase I analyses of twelve composite surface (0-1 ft depth) soil samples indicated the presence of trace PCBs (below 3 mg/kg). Lead levels in surface soils were not dissimilar to levels detected at the control sites but were slightly higher. Geophysical surveys suggested the presence of some subsurface objects. Therefore, Phase II included exploration test pits to a depth of seven feet along a transverse gully highlighted in the geophysical survey. One of five test pits showed elevated levels of PCBs and lead. Analyses of four ground water wells showed total unfiltered levels of chromium, copper, iron, manganese and chloroform concentrations above the regulatory criteria. The other ground water samples contained manganese and iron above the Federal MCL and Illinois Public Water Supply Standards. PCBs were not detected in any of the ground water wells at a detection level of 1 ug/L.

Due to the presence of one localized deep pocket of contaminants, it is recommended that remedial alternatives for this site be addressed in the FS.

Site 29, Fire Station Landfill: This large field behind the Refuge Fire Station was previously used for storage of mining machinery. The field was reportedly also used by Olin Corp. as a landfill site. Phase I analyses of seven composite surface soils (six grabs each, three along the northern

face and three along the eastern face of the field) indicated the presence of lead and magnesium. The levels of these contaminants were within roughly one order of magnitude of the concentrations detected at the control sites, while zinc and mercury levels were close to the levels detected for background.

Phase II investigations included ten subsurface soil exploration pits (five on the north face and five on the east face) to a depth of six feet. The soil contained magnesium and lead up to concentrations of 40,300 and 2,350 mg/kg, respectively; these levels are one to two orders of magnitude above the concentrations detected at the control sites. The highest lead concentration was detected in a sediment transect from a wet area adjacent to the eastern face. Four groundwater wells were installed and sampled. The ground water contained total iron and manganese concentrations exceeding the Federal MCL and Illinois Public Water Supply Standards. One well contained selenium above the standards; another contained benzene above the AWQC for human health.

Based on the risk assessment, lead levels in exposed sediments could possibly result in harmful exposure levels for wildlife, but humans would not be affected. It is recommended that remedial measures at this site be addressed in the FS.

Site 32, Area 9 Landfill: This site is an inactive landfill that was reportedly used as a disposal area for capacitor manufacturing and other mixed wastes. Phase I analyses of surface and core soils to a depth of 12 ft. from the landfill, and analyses of surface sediments and 6 ft. cores from adjacent creeks and transects, indicated elevated concentrations of PCBs (maximum 13,000 mg/kg wet wt.) and lead (maximum 6,270 mg/kg). Some dioxin/furan isomers were detected but the levels encountered were

within the range that would normally be associated with the detected PCB concentrations. Commercial PCB aroclor mixtures contain low levels of dioxin/furan constituents.

PCBs were detected in all thirty soil and twelve sediment samples collected during Phase II, but at levels below 5 mg/kg wet wt. with only three exceptions. All but one of the Phase II soil samples contained lead at concentrations above the Refuge background. One ground water sample contained chromium exceeding the Federal MCL and the Illinois Public Water Supply standards. Detectable PCB concentrations in ground waters were below 0.1 ug/L but were above the AWQC for protection of human health.

The evaluation of environmental effects concluded that site contaminants could pose a risk to potential receptors, specifically sensitive wildlife. Based on a quantitative risk assessment, and since human exposure is limited due to the location of the site, protection of wildlife should be addressed in the remediation efforts. It is recommended that further evaluation of this site be conducted in the FS.

Site 33, Area 9 Building Complex: Site 33 consists of a building complex that was formerly used to manufacture various types of capacitors and is currently occupied by an explosives manufacturer. Phase I investigations involved the collection of 188 soil samples at various locations at depths up to 3 ft., to investigate the extent of contamination. Elevated PCB concentrations above 50 mg/kg were present mainly within the areas adjacent to two buildings where capacitors and transformers were formerly manufactured or stored. PCB levels were also found to be elevated up to 3 ft deep in some locations along two drainage ditches leading from the industrial complex toward Crab Orchard Lake.

Phase II analyses of soils from 61 additional locations (up to 6 ft depth) served to further define the extent of contamination. Metals, including lead, and organics were generally consistent with the levels detected at the control sites for selected samples which were analyzed for these parameters. Phase II analyses of ground water samples from three wells indicated the presence of PCBs below 1 ug/L but above the AWQC for protection of human health. Trichloroethene was detected in one well sample above the AWQC. Chromium was the only parameter (in groundwater) which exceeded the Federal MCLs and Illinois Public Water Supply Standards.

Contaminant levels were found to present a potential risk to inherent wildlife, although humans could also be subject to exposure if trespassing through areas where contaminants are found. It is recommended that remediation of this site should be further addressed in the FS.

Site 34, Crab Orchard Lake: Phase I analyses of five surface water samples from current or potential drinking water sources indicated that, other than manganese and trihalomethane residuals, all concentrations were below the standards for Illinois Public Water Supplies, Federal drinking waters, and AWQC. Corrective measures have since been instituted to reduce trihalomethane levels in treated supplies to within the standards. The excursions for manganese do not represent a health concern since the standard for this chemical is established for control of taste and odor in waters. Thirty composite fish samples were collected during Phase I and were analyzed in Phase II for pesticides/PCBs, mercury, cadmium, and lead.

Additional Phase I investigations consisted of resampling the five current or potential drinking water sources as well as collecting ten lake

sediments and ten lake water column samples. The lake water samples were collected at three depths from locations in the eastern and western areas of the lake. The City of Marion treated water contained bromodichloromethane and chloroform at concentrations above the Federal MCL for trihalomethanes. The Refuge treated water also contained these two trihalomethanes. The presence of trihalomethane compounds such as chloroform and bromodichloromethane arises from chlorination of treated water supplies. As noted above, the City has taken measures to correct these excursions and now is in full compliance with the standards, according to IEPA drinking water officials. Trace levels of cyanide were detected in one sample from the City of Marion treated supply (but not detected in a duplicate sample) but were below U.S.EPA's lifetime health advisory level for this compound. No PCBs were detected in any of these samples at a detection limit of 5 parts per trillion.

Water column samples from Crab Orchard Lake generally met all Federal and State criteria and standards. However, one sample contained mercury, one contained cyanide and three contained arsenic concentrations above the AWQC for human health. The cyanide concentration was below U.S.EPA's lifetime health advisory level, however. Three water columns near Area 9 on the east end of the Lake contained detectable (less than 0.02 ug/L) PCB concentrations, but only one sample was above the AWQC for protection of aquatic life. Some sediment samples contained arsenic, phthalate esters, and several organics, including PCBs.

Of the thirty fish samples, two carp composites exceeded the Food and Drug Administration's (FDA) action level of 2.0 mg/kg for PCBs in edible tissue, and one bass was slightly over the FDA action level of 1 mg/kg for mercury. All three of these samples were collected in the

eastern end of the Lake. The two samples with PCB levels of 3 and 6.4 mg/kg (4.4 and 3.9 mg/kg when re-analyzed) were collected outside the Area 9 embayment. PCB levels in the remaining fish samples were well within the criteria, and most were below the detection level of 0.4 mg/kg). All samples collected from the western end of the lake where recreational fishing is permitted were below the FDA action levels, and were not considered to represent undue risks of exposure to either humans or wildlife.

Assessment of this site also included data generated by several State and City regulatory and monitoring programs for Crab Orchard Refuge. A suggested follow up sampling and monitoring program has been detailed in Attachment 1. Given the circumstances of Crab Orchard Lake, including observed fishing patterns, the remedial measures contemplated for various on-land potential PCB sources, the low levels and limited areas of measured PCB concentrations in lake sediments, the health of the existing aquatic ecosystem, and the natural self-sealing mechanism provided by the lake sedimentation, direct remediation of lake sediments is not recommended. For these reasons, this site will not be considered further in the FS.

Site 35, Area 9 East Waterway: This site is a low-lying spot in a field where contamination was suspected due to the lack of vegetation. Phase I analyses of one soil sample indicated unusually high specific conductance. Trace parts per billion levels of PCBs were detected in the soil sample. No Phase II sampling was conducted.

Contaminant levels were not considered to represent a concern or risk of exposure. No further evaluation of this site is recommended, therefore, this site will not be addressed in the FS.

EXECUTIVE SUMMARY - TABLE 1 (p. 1 of 3)

WATER ANALYSES OUTSIDE CRITERIA OR STANDARDS

		All concentrations in ug/L																							
		BENZ	BRCL2CN	CCL4	CHCL3	CHCCL3	PNCLPNOL	PCB	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Se	Cn							
		(See abbreviations on Page 3)																							
ILLINOIS Standards																									
General Use																									
Public Water Supply																									
FEDERAL Drinking Water Stds.																									
MCL & SMCL		5		5					50	10	50	1000	300	50	50	2	10								
MCLG		0		0		0	220 #	0	50	5	120	1300		20 #		3 #	45 #								
AMBIENT WATER QUALITY CRITERIA																									
Freshwater Aquatic Life (24hr avg)		3100	+	620	500	+	6.2	0.014	57							+	9.7	4.2							
Freshwater Aquatic Life (Max)		7000	+	1400	1200	1500	14	2	130							+	22	22							
Human Health (10E-06 Risk)		1.5	2.0*	0.26	0.21	2.1	140*	7.9E-05	0.002	10*	(2)	1000*		50*		0.2*	10*	200*							
SITE		I.D.		PHASE																					
Area 11 Acid Pond		5-1	I														500		100						
D Area SE Drainage Ch.		7-1	I														3200		1500						
D Area SW Drainage Ch.		8-1	I																160						
Waterworks No. Drainage		10-1	I														600		270						
P Area Southeast Dr. Ch.		11-1	I	3		31																90			
Solv. Stor. Ditch (Down)		14-1	I	5		43														600		180			
" " (Upstream)		14-3	I			11																			
" " (Upstream)		14-5	II	23		123																			
Acid Pond Water		15-1	I														1000								
Acid Pond Water		15-3	II														0.01								
Area 7 Ind. Ditch(Down.)		16-1	I																340						
" " (Upstream)		16-3	I		66	77																70			
Job Corps Groundwater		17-8	II														0.01								
"		17-9	II														15								
"		17-10	II														19	2.4	139						
"		17-11	II														0.022	74	55						
"		17-65	II														0.066								
Job Corps Pond		17-14	II														0.058								
"		17-16	II														0.032								
Refuge Shop Ditch		22-8	II															25			70				
Pepsi West Drainage		24-1	I																						
COC @ Marion LF (Down.)		25-1	I																1510						
" " (Upstream)		25-3	I																680						
" " (Pond)		25-5	I																720						
COC - Marion STP (Down.)		26-1	I																300						
" " (Upstream)		26-3	I																750						
COC Below 157 Drdge Area		27-1	I																640						
Water Tower LF Well		28-7	II																640						
"		28-15	II																3110	357					
"		28-8	II																425						
"		28-16	II		10														165	117	94600	76	2780		

EXECUTIVE SUMMARY - TABLE 1 (p. 2 of 3)

WATER ANALYSES OUTSIDE CRITERIA OR STANDARDS

		All concentrations in ug/L																
		BENZ	BRCL2CH	CCL4	CHCL3	CHCCL3	PNCLPHOL	PCB	As	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Se	Cn
		(See abbreviations on Page 3)																
ILLINOIS Standards																		
General Use									1000	50		20	1000	100	1000	0.5	1000	25
Public Water Supply									50	10	50	20	1000	50	150	0.5	10	25
FEDERAL Drinking Water Stds.																		
MCL & SMCL		5		5					50	10	50	1000	300	50	50	2	10	
MCLG		0		0		0	220 #	0	50	5	120	1300		20 #		3 #	45 #	
AMBIENT WATER QUALITY CRITERIA																		
Freshwater Aquatic Life (24hr avg)		3100	+	620	500	+	6.2	0.014	57							+	9.7	4.2
Freshwater Aquatic Life (Max)		7000	+	1400	1200	1500	14	2	130							+	22	22
Human Health (10E-06 Risk)		1.5	2.0*	0.26	0.21	2.1	140*	7.9E-05	0.002	10*	(2)	1000*		50*		0.2*	10*	200*
SITE		I.D. PHASE																
Fire Station LF Well		29-8	II	4														
"		29-9	II															
"		29-10	II															
"		29-11	II															
Area 9 LF Well		32-61	II															
"		32-62	II															
"		32-63	II															
"		32-109	II															
Area 9 Bldg Complex Well		33-340	II															
"		33-341	II															
"		33-342	II															
Marion Reservoir Intake		34-3	I															
Refuge Treated Water		34-4	I															
Marion Treated Water		34-5	I															
Refuge Treated Water		34-65	II															
Marion Treated Water		34-66	II															
Crab Orchard Lake 18		34-6	II															
"		34-7	II															
"		34-8	II															
"		34-11	II															
"		34-15	II															

EXECUTIVE SUMMARY - TABLE 1 (p. 3 of 3)

WATER ANALYSES OUTSIDE CRITERIA OR STANDARDS

REFERENCES (See Tables 6-1,2,3 of Volume 1)

SYMBOLS

- (#) Proposed Maximum Contaminant Level Goal
- (+) Insufficient Data to establish criteria.
- (*) Criterion based on health effects other than $10E-06$ risk level.
- LF= Landfill

NOTES

- (1) AWQC for Aquatic Life, (Proposed 1984), Cd
Avg: $\exp(1.3[\ln(\text{ppm hardness})]-3.92)$ ug/L
Max: $\exp(0.87[\ln(\text{ppm hardness})]-4.38)$ ug/L

- (2) AWQC for Aquatic Life, (Proposed), Cr
Avg: $\exp(0.819[\ln(\text{ppm hardness})]+0.537)$ ug/L
Max: $\exp(0.819[\ln(\text{ppm hardness})]+3.568)$ ug/L

AWQC for Human Health, Cr (IV)

$8.0E-04$ ug/L is being considered by USEPA as a possible criteria at an interim target risk level of $10E-06$. Current regulations establish the criterion for human health at 170 ug/L (Cr III), and at 50 ug/L (Cr VI).

ABBREVIATIONS

BENZ	Benzene
BRCL2CH	Bromodichloromethane
CCL4	Carbon Tetrachloride
CHCL3	Chloroform
CHCCL3	Trichloroethene
PNCLPHOL	Pentachlorophenol
PCB	Polychlorinated Biphenyls

NOTES (Continued)

- (3) AWQC for Aquatic Life, (Proposed), Cu
Avg: $\exp(0.905[\ln(\text{ppm hardness})]-1.785)$ ug/L
Max: $\exp(0.905[\ln(\text{ppm hardness})]-1.413)$ ug/L

- (4) AWQC for Aquatic Life, (Proposed), Pb
Avg: $\exp(1.34[\ln(\text{ppm hardness})]-5.245)$ ug/L
Max: $\exp(1.34[\ln(\text{ppm hardness})]-2.014)$ ug/L

- (5) Data questionable; see Section 38.3.1.

- (6) Not detected in a duplicate sample.

EXECUTIVE SUMMARY - TABLE 2 (p. 1 of 2)

GENERAL RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

RESPONSE ACTION	FEASIBLE REMEDIAL TECHNOLOGIES	3	4	5	7	7A	8	9	10	11	11A	12	13	14	15	16	17	18	19	20	21	22	24	25	26	27	28	29	32	33	34	35
NO FURTHER EVALUATION					X	X	X	X				X	X	X				X		X	X		X									X
MONITORING									X	X				X		X								X	X	X						X
NO ACTION	Monitoring, Fencing, Site Use Limitations	*	*	*	X		X	X	X	X					X		X		*	X	X	X		X	X	X	X	X	X	X		
CONTAINMENT	Dams, Ground Water Barriers, Bulkheads, Capping, Sealing														X		X					X				X	X	X	X			
PUMPING	Ground or Surface Water, Sediment Dredging														X		X					X							X	X		
COLLECTION	Sedimentation Basins, Subsurface Drains																											X	X			
DIVERSION	Dikes, Berms, Grading Stream Diversion, Ditches, Terraces, Chutes, Downpipes														X		X					X			X	X	X	X				
COMPLETE REMOVAL	Excavation of Wastes, Soil/Sediment; Tanks, Drums, Liquid Wastes														X		X					X				X	X	X	X			
PARTIAL REMOVAL	Selective Excavation of Wastes, Soil/Sediment; Tanks, Drums, Liquids														X		X					X				X	X	X	X			
ON-SITE TREATMENT	Biological, Chemical, or Physical Treatment, Incineration, Solidification, Land Treatment, Vitrification														X		X					X				X	X	X	X			
OFF-SITE TREATMENT	Treatment/Storage/Disposal Facility, Incineration, Solidification, Vitrification																X					X				X	X	X	X			

EXECUTIVE SUMMARY - TABLE 2 (p. 2 of 2)

GENERAL RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

RESPONSE ACTION	FEASIBLE REMEDIAL TECHNOLOGIES	SITE NO. (See Table 1-1 for Site Names)																															
		3	4	5	7	7A	8	9	10	11	11A	12	13	14	15	16	17	18	19	20	21	22	24	25	26	27	28	29	32	33	34	35	
IN-SITU TREATMENT	Permeable Treatment Beds, Bio-Reclamation, Neutralization, Land-farming														X		X					X								X	X		
STORAGE	Temporary Structures																																
ON-SITE DISPOSAL	Landfill, Land Application																X					X					X	X	X	X			
OFF-SITE DISPOSAL	Landfill, Surface Impoundments, Land Application																X					X					X	X	X	X			
ALTERNATIVE WATER SUPPLY	Cisterns, Above ground Tanks, Deeper/Upgradient Wells, Municipal Water, Relocation of Intake, Specific Treatment Devices										X																						
RELOCATION	Temporary/permanent relocation of animal populations																X													X	X		

NOTES:

Sites 30 and 31 were established as control sites and therefore are not included in the evaluation of remedial options.

(*) The Refuge Management has indicated that the Department of Defense will be responsible for further remedial investigations.

TABLE 1-1
STUDY SITES

<u>Site Number</u>	<u>Name</u>
3	Area 11 South Field
4	Area 11 North Field
5	Area 11 Acid Pond
7	D Area SE Drainage Channel
7A	D Area North Lawn
8	D Area Southwest Drainage Channel
9	P Area Northwest Drainage Channel
10	Waterworks North Drainage Channel
11	P Area Southeast Drainage Channel
11A	P Area North
12	Area 14 Impoundment
13	Area 14 Change House
14	Area 14 Solvent Storage Drainage Ditch
15	Area 7 Plating Pond
16	Area 7 Industrial Site
17	Job Corps Landfill
18	Area 13 Loading Platform
19	Area 13 Bunkers
20	D Area South Drainage Channel
21	Southeast Corner Field
22	Old Refuge Shop Drainage Pool
24	Pepsi-West Drainage Ditch
25	Crab Orchard Creek at Marion Landfill
26	Crab Orchard Creek Below Marion STP
27	Crab Orchard Creek Below 157 Dredge Area
28	Water Tower Landfill
29	Fire Station Landfill
30	Refuge Control
31	Munitions Control
32	Area 9 Landfill
33	Area 9 Building Complex
34	Crab Orchard Lake
35	Area 9 East Waterway

SECTION 1 - INTRODUCTION

1.1 Background

The Crab Orchard National Wildlife Refuge ("the Refuge") is located in Williamson County in southern Illinois as shown in Figures 1-1 and 1-2. The Refuge is owned by the U.S. government and is currently administered by the U.S. Fish and Wildlife Service (FWS) of the U.S. Department of the Interior (DOI).

The Refuge was previously administered by the U.S. Department of Defense (DOD) at which time several industries operated on the eastern portion of the Refuge. These industries were primarily involved in the manufacture of munitions, although non-military industries also operated. The Refuge was turned over to the FWS subsequent to World War II. Some industrial tenants have continued their operations at the Refuge under its administration by FWS, others have left or have been replaced by other private or federal concerns.

Investigations have been conducted by the DOI, the U.S. Environmental Protection Agency (USEPA) and the Illinois EPA since the late 1970s and have indicated the presence of elevated levels of such contaminants as polychlorinated biphenyls (PCBs) and lead at several sites on the Refuge (see Section 2). Based on the findings of these investigations and previous usage of Crab Orchard Lake as an auxiliary source of water intake for the Marion Reservoir, a nearby public water supply, the USEPA added the Refuge to the National Priorities List (NPL) in 1984. Consequently, the DOI and Sangamo Weston, Inc. jointly initiated a Remedial Investigation/Feasibility Study (RI/FS) of the Refuge.

Sangamo Weston, Inc. is one of the industries that operated at the Refuge between 1946 and 1962. Sangamo's operations consisted of the manufacture of electrical components such as capacitors.

The RI/FS was conducted for thirty-three sites located at the eastern end of the Refuge. The sites are listed in Table 1-1, and their locations are shown in Figure 1-3. Two of the thirty-three sites were included to serve as control sites. Most sites are located near tributaries that drain into Crab Orchard Lake.

This report presents the results of site investigations conducted as part of the RI. Section 2 contains background information on the Refuge and previous studies. Section 3 provides the rationale for the approach to the site investigations, which were conducted in two phases, and the basis for the selection of sampling locations and analytical parameters. General field activities and procedures are described in Section 4, and the development of the analytical data presented in this report is discussed in Section 5. Section 6 describes the methods used to evaluate the environmental impacts of each site, and Section 7 outlines the procedures for identification of preliminary remedial alternatives.

The site investigations sections are described in Sections 8 through 39. These sections contain details of the sampling activities and analytical data for each specific study site. The environmental impacts of the detected contaminants are discussed, and potential remedial alternatives are identified.

1.2 Purpose of the RI/FS

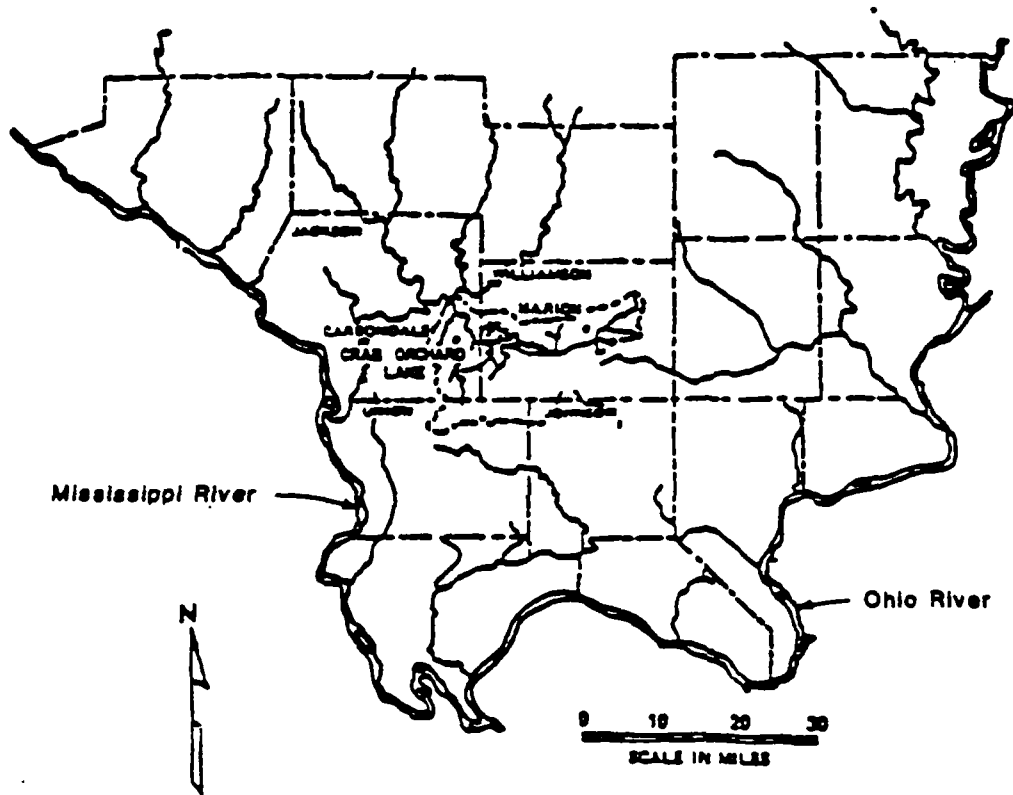
Preliminary data collected at various locations in the Refuge suggested that PCBs, lead, zinc, arsenic and explosives residuals may be

STATE OF ILLINOIS



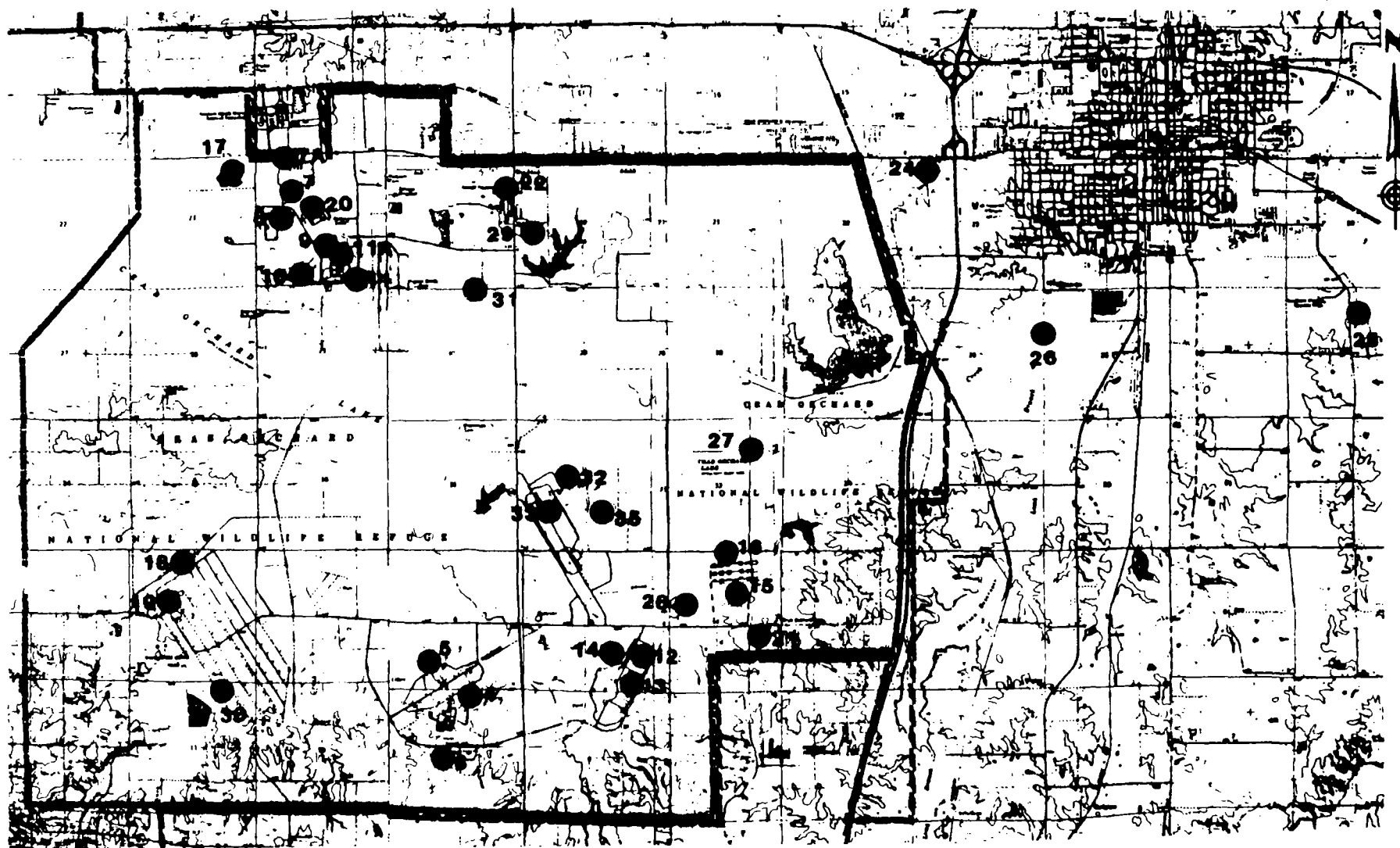
Location of Crab Orchard National Wildlife Refuge

CRAB ORCHARD CREEK BASIN



ADAPTED FROM U.S.D.O.I. GEOLOGICAL SURVEY STATE OF ILLINOIS, 1970

FIGURE 1-8



REFUGE BOUNDARY
CLOSED AREA
SCALE IN FEET
0 4000 8000

CRAB ORCHARD NATIONAL WILDLIFE REFUGE
LOCATIONS OF SAMPLING SITES

found at some locations within the Refuge. Additional data were required to determine the extent and impact of the problems at the sites where contamination had been detected.

The purposes of the Remedial Investigation (RI) for the Crab Orchard Refuge are:

- 1) to determine the nature, magnitude, and extent of contamination at the thirty-three sites listed in Table 1-1, and
- 2) to assess the risks of damage to human health, welfare, and the environment due to the contamination, and
- 3) to gather the data necessary for the Feasibility Study.

The purposes of the Feasibility Study (FS), which will be undertaken after completion of the RI, are:

- 1) to identify and evaluate remedial alternatives, and
- 2) to identify the most cost-effective and environmentally sound remedial actions to be undertaken at the contaminated sites.

1.3 Scope of the RI/FS

The U.S. DOI issued a draft Scope of Work on December 12, 1984 for the RI/FS at the Crab Orchard NWR. Subsequently, several documents were developed based on discussions between the U.S. DOI, U.S. FWS, USEPA, Illinois EPA, Sangamo Weston, Inc. and O'Brien & Gere to define the scope of the RI/FS. These documents include the following:

- Scope of Work, February 1985, updated April 1985 and June 1985
- Work Plan, June 1985 - included Site Health & Safety Plan and Quality Assurance Project Plan (QAPP)
- Work Plan Supplement, December 1985

- Work Plan Supplement - Phase II, April 1986, September 1986, October 1986 and November 1986
- Quality Assurance Project Plan (QAPP) - Phase II, May 1986, September 1986, October 1986 and November 1986

A list of the references used as background for the RI/FS is included at the end of this report.

The RI consisted of eight tasks:

- Task 1 - Description of Current Situation
- Task 2 - Investigation Support
- Task 3 - Site Investigation
- Task 4 - Preliminary Remedial Technologies
- Task 5 - Site Investigations Analyses
- Task 6 - Final Report
- Task 7 - Community Relations
- Task 8 - Additional Requirements

The FS also consists of eight tasks:

- Task 9 - Description of Proposed Response
- Task 10 - Development of Alternatives
- Task 11 - Initial Screening of Alternatives
- Task 12 - Laboratory Studies
- Task 13 - Evaluation of Alternatives
- Task 14 - Final Report
- Task 15 - Conceptual Design
- Task 16 - Additional Requirements

The FS Report will be prepared following approval of the RI Report by USEPA and FWS. See also Section 7 of this Report.

SECTION 2 - REFUGE HISTORY AND CHARACTERISTICS

2.1 General

Crab Orchard Refuge is located in the southern region of the State of Illinois (see Figures 1-1 and 1-2). The Refuge comprises an area of 42,620 acres and lies primarily within Williamson County but extends into neighboring Jackson, Union and Johnson Counties. There are twelve lakes, including Crab Orchard Lake, located within the Refuge. The western end of the Refuge around Crab Orchard Lake is used for recreational purposes while the eastern end is used for manufacturing facilities.

2.2 Ecology

The Refuge habitat includes 21,000 acres of forested land, 3,000 acres of pine plantations and 11,000 acres of cultivated land. Crab Orchard Lake supports a large population of largemouth bass, channel catfish, bluegill, sunfish, and crappie, which are available to sports fishermen. Wildlife on the Refuge include white-tailed deer, cottontail rabbits, geese, ducks and bobwhite quail as well as many non-game species (Ruelle, April 1984). In addition, there are two active bald eagle nests on the refuge, one on the southeast side of Grassy Bay and one on the northeast corner of Little Creek (Ruelle, 1987). Bald eagle habitats are classified as Essential Habitat for 640 acres (one square mile) around the nest.

2.3 Regional Physiography and Geology

The construction of Crab Orchard Lake was completed in 1940. The lake has a surface area of 6,965 acres, a watershed drainage area of 109,261 acres, and a storage capacity of 72,525 acre-feet. The eastern portion of the lake is

two to three feet deep, while the western portion has an average depth of 8-9 feet with a maximum depth of thirty feet. The lake has a retention time of approximately 0.8 years (Kelly and Hite, 1981). Water enters the lake through several creeks, including Crab Orchard Creek on the eastern end of the lake. Water exits the lake through a continuation of Crab Orchard Creek on the western end of the lake. According to Refuge personnel, 280,000 gallons of water are treated daily at the Refuge water treatment plant for use by Refuge personnel and the nearby Marion Federal Penitentiary. Water samples are collected at least quarterly by the Refuge Water Treatment plant operators for laboratory characterization.

The physiographic designation of the region is the Shawnee Hills section of the interior low plateau province of Southern Illinois (USDA, 1959). Drainage in the area is generally toward Crab Orchard Lake which then discharges into Crab Orchard Creek and Drury Creek below the spillway located on the western end of the lake. Ultimate discharge is then to the Mississippi River located approximately twenty miles west of the lake. The area is located at the terminus of the Illinoian continental glaciation (Frye, 1965). Therefore, portions of the land surface in the area are glaciated, particularly north of Crab Orchard Lake, and some portions south of Crab Orchard Lake are unglaciated but covered with glacial outwash loess and modern alluvium. The resulting topography in the area is complexly dissected with narrow ridge tops between deeply incised valleys (USDA, 1959). Elevational relief in the area is generally about 150 feet between 400 and 550 feet msl, United States Geodetic Survey. The spillway elevation of the lake is 405 feet msl.

The soils occurring in the area of study consist of an upper layer of well developed, fine grained silt known as Loess deposited by wind during the various glacial periods (USDA, 1959). The thickness of this unit varies from

non-existent to greater than 15 feet in some places. Fill and trash deposited at some of the sites investigated have been incorporated into upper portions of this unit. Underlying this unit, a fine grained glacial till unit occurs which consists of silt and clay with some discontinuous sand lenses occurring particularly in the basal portion. The thickness of this unit ranges from about 10 to 70 feet.

The bedrock which underlies the soil sequence consists of Pennsylvanian Age sandstones and shales known as the Carbondale Formation (American Association of Petroleum Geologists, 1965). The upper portion of the bedrock sequence penetrated by split spoon sampling consisted predominantly of sandstone. The area is situated near the southern limit of the Illinois basin structural feature. As a result, the bedrock in the area dips gently to the north and northeast.

2.4 Climate

The climate in southern Illinois is classed as humid continental with mild winters and relatively warm, humid summers. At the Carbondale Station located to the west of the site, data accumulated since 1910 indicate that the warmest month, July, has a mean temperature of 79.3 deg. F. January, the coldest month, averages about 34.9 deg. F. Average annual rainfall is 44.7 inches and average snowfall is 13.6 inches. May is normally the wettest month and February, the driest. The average frost-free date in the fall is October 22 (U.S.D.A., 1968).

2.5 Land Use

The area occupied by the Crab Orchard Refuge was used for agriculture in the 1920s and 1930s. During the early 1940s, World War II spurred the

development of several wartime manufacturing industries on the eastern end of Crab Orchard Lake. The U.S. Army and a number of contractors leased portions of the Refuge for the production of munitions and other products. The manufacture of bombs, land mines, and explosives were the principal industries at that time. However, companies involved in metal fabrication, plating, manufacture of printing inks, and electrical components are also reported to have occupied sites on the Refuge. Several industries reportedly landfilled wastes generated as part of their manufacturing activities in nearby locations.

At the end of World War II, the U.S. Army turned the Refuge over to the U.S. DOI for use as a National Wildlife Refuge. After the war other industries moved onto the site to occupy buildings formerly used by the wartime industries. Electrical capacitors and transformers containing PCBs were manufactured until the early 1960s. (Adams, W.D., May 24, 1984.) Automobile parts, fiberglass boats, corrugated boxes, plated metal parts, tape, flares and jet engine starters were also manufactured at different sites within the Refuge. According to the Refuge Manager, landfills and dumps were used by these industries to dispose of wastes generated in these operations. The production of explosives continues to be the principal industry on the Refuge. Many of the storage bunkers on the Refuge continue to be used by commercial concerns for storage of munitions. Because of the nature of the industrial activities and the extensive wooded areas, the Refuge maintains a fully-staffed fire station. However, the Refuge is currently phasing out the fire department. Fire protection has or soon will be contracted out to local municipalities.

Public access is generally limited to authorized personnel on the eastern portion of the Refuge, as shown on Figure 1-3. Individual industries have

security checkpoints for access to their facilities. Most of the abandoned industrial buildings, as well as the active manufacturing areas, are within fenced areas or are along roadways which are locked to the public. Unoccupied areas are also locked to the public to protect wildlife and the ecology.

2.6 Demographics

The Refuge is a popular fishing, hunting, camping and recreation area. Over one million visitor use days per year are reported (Arnett, 1984). Most of this usage occurs on the western portion of the Refuge, which is remote from the manufacturing areas.

According to the Refuge Manager, Crab Orchard Lake water is treated on-site at the Refuge Water Treatment Plant to supply the Refuge and its industrial tenants, as well as a nearby penitentiary. It is proposed, however, to integrate the Refuge and the City of Herrin water lines, to obtain water from Rend Lake, a surface supply located north of Marion. This proposed program, if instituted, will substantially alleviate operating costs for the Refuge, since the Refuge Water Treatment Plant currently relies on older process equipment which is more costly to operate. Thus, use of Crab Orchard Lake as a drinking water supply is expected to terminate within approximately two years.

IDPH (1976-1987) monitoring data of Crab Orchard Lake treated water supply have shown levels of manganese that have exceeded the Secondary Maximum Contaminant Level (SMCL) of 0.05 mg/L for manganese and the Illinois State public water supply standard of 0.15 mg/L for manganese. A review of these data by the Agency for Toxic Substances and Disease Registry (ATSDR, 1986) concluded that these excursions do not pose a public health

risk since these standards were established based on aesthetic concerns. In addition, data gathered from this monitoring program (IDPH, 1976-1987) have shown that Crab Orchard Lake water has also exceeded the Maximum Contaminant Level (MCL) of 0.10 mg/L for total trihalomethanes (TTHM) on several sampling occasions prior to 1986. A sample of untreated (raw) lake water collected at the Refuge Water Treatment Plant (WTP) exhibited no trihalomethanes above the method detection limit of 0.1 ug/L. In sampling surveys prior to 1986, finished water samples taken from various areas at the Refuge complex exhibited TTHM concentrations above the Federal MCL for TTHM, indicating that the water treatment process, and not the raw lake water, is the source of TTHM compounds. Chloroform was found to be the largest contributor to the TTHM concentrations. The formation of trihalomethanes is a common occurrence in the treatment of surface water supplies. These compounds form by the combination of humic substances in the raw supply and chlorine added in the treatment process. Corrective measures have been instituted by the Refuge management such that all samples collected after 1986 in this monitoring program have not exhibited TTHM levels above the drinking water standards.

Treated water (from the Refuge WTP) collected at the Marion Federal Penitentiary has also exhibited TTHM concentrations above the MCL of 0.10 mg/L for TTHMs. All other parameters were below the Illinois and Federal standards. Sampling and analyses of water sources within the prison have shown these excursions occurring as early as October 1982 and continuing through the most recent sampling (June 1987). Once again, chloroform was found to be the largest contributor to the TTHM concentrations. Corrective measures have been taken, however, to lower TTHM levels in the treated water supplies to acceptable levels.

The City of Marion is located upgradient and adjacent to the northeast boundary of the Refuge. The city supports a population of 13,000 (Illinois EPA, 1981). The city obtains its water supply from the Marion Reservoir, approximately two miles east of Crab Orchard Lake. It is reported that during dry seasons, Crab Orchard Lake was previously used as an auxiliary intake for the City of Marion. The last withdrawal occurred in 1981, when the city supplemented approximately 6 percent of its total water supply volume using water drawn from Crab Orchard Lake. Currently, the City uses water from Herrin Lake as an auxiliary intake, and Crab Orchard Lake will not be used except as a last alternative, according to the City Engineer. During the period from November 2, 1987 continuing through December 1987 an estimated 2.4 million gallons have been withdrawn daily from Herrin Lake to supplement the Marion Reservoir. Capacity of the Marion Reservoir is reportedly 450 million gallons.

Data gathered through a continuing monitoring program conducted by IDPH (1976-1987) showed that the public drinking water supply for the City of Marion has exhibited TTHM concentrations that have exceeded the MCL of 0.10 mg/L for TTHMs; all other parameters were found to be within the applicable State and Federal Drinking Water Standards. The formation of trihalomethane compounds arises from the chlorination treatment of water and is not indicative of contamination in the raw water supplies.

2.6.1 Private Ground Water Users

An inventory of ground water users was performed in the area of study to identify the nature and location of private and commercial wells. The Illinois State Water Survey Division of the Illinois Department of Energy and Natural Resources was contacted for this information. Well

locations and identification numbers, as stated in the survey, are plotted on Figure 2-1. Well logs and a descriptive summary are presented in Appendix C.

Results of the survey indicate that numerous wells are present in the surveyed area in a radius of approximately 2 miles around the eastern half of Crab Orchard Lake. The wells consist of shallow-dug wells set with brick casing in clay which are used mostly for residential purposes, and drilled wells set at depths of 30 to 200 feet in sandstone and shale bedrock. Most of these wells may have been established in the 1940s or 1950s. According to the Refuge Manager, within the boundaries of the Refuge, none of the ground water wells are currently in use.

2.7 Previous Investigations

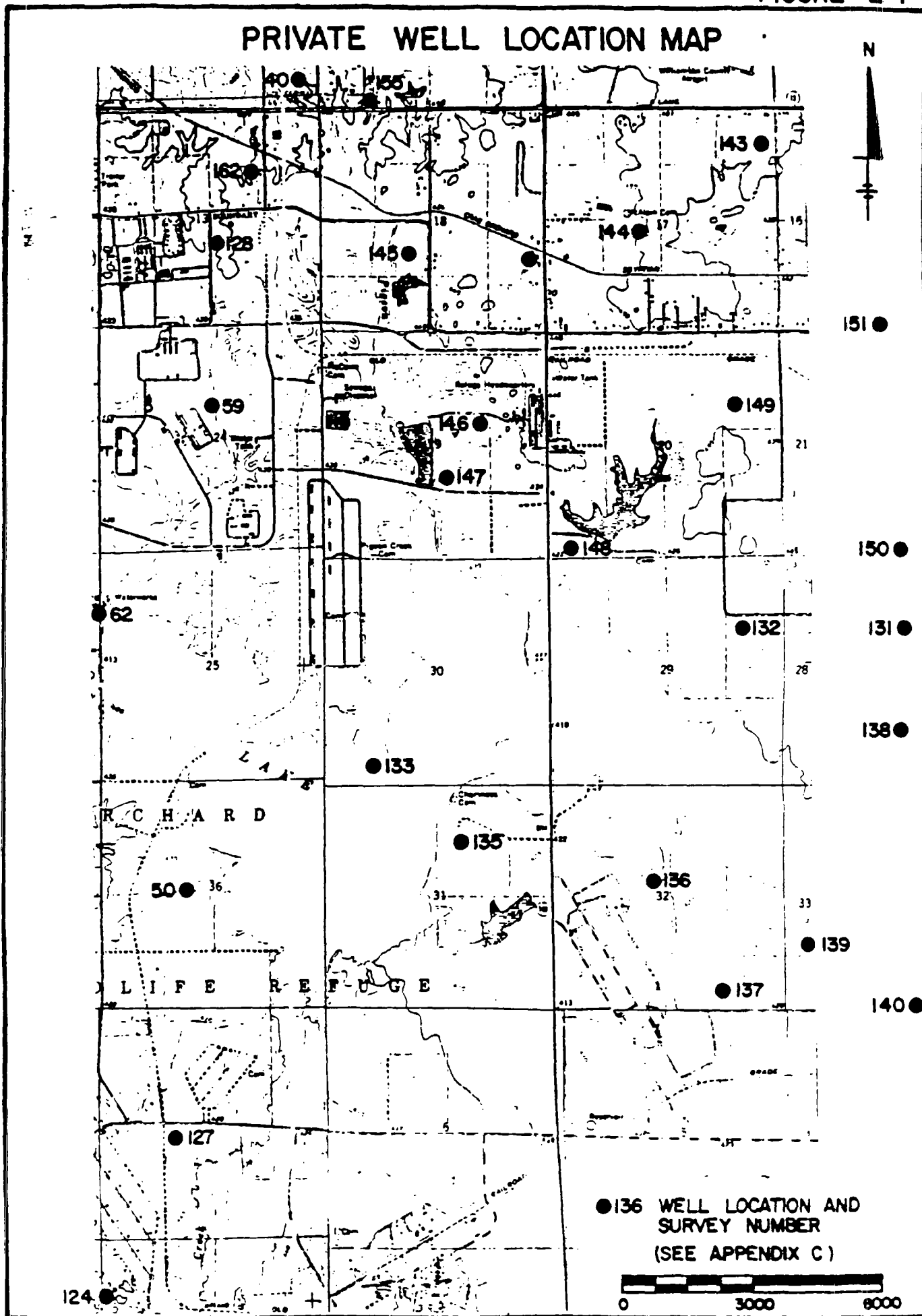
Several investigations have been conducted since the late 1970s. These investigations are described below.

2.7.1 Sediment Investigations

Early investigations (Hite and King, 1977; Kelly and Hite, 1981; and Illinois EPA, 1981) focused on evaluations of benthic deposits in Crab Orchard Lake and in Crab Orchard Creek downstream of the Marion Wastewater Treatment Plant.

In the summer of 1979 (Kelly and Hite, 1981), 273 sediment samples from 63 lakes in Illinois were analyzed for metals, PCBs, dieldrin, heptachlorepoxyde and DDT. The concentration of metals in Crab Orchard Lake sediments were well within the range of values for all lakes in Illinois, and in most cases below the state-wide averages. PCBs, dieldrin, heptachlorepoxyde and DDT were below detection levels (less

PRIVATE WELL LOCATION MAP



than 10, less than 1, less than 1 and less than 5 ppb, respectively) in Crab Orchard Lake sediments.

Limited data were previously developed on surface water and sediments from creeks discharging to Crab Orchard Lake. In July 1982 (Ruelle, March 1983), low levels of PCBs were found in sediments from five Crab Orchard Lake tributaries: PCB concentrations were 0.12 ppm in Crab Orchard Creek sediment, 0.09 ppm in Grassy Creek (located west of Area 9), 0.04 ppm in Wolf Creek (west of Area 9), 0.38 ppm in Pin Oak Creek and 0.20 ppm in Pigeon Creek (north of the lake).

Surface sediments from an intermittent creek opposite Area 9 had 44 ppm PCBs (dry weight), and 2.4 to 16 ppm PCBs close to the lake. Soil samples at a 1-foot depth in the intermittent creek opposite the Area 9 Landfill contained 4.4 ppm PCBs.

Analysis of Crab Orchard Lake sediments from fourteen locations on May 25-26, 1983 (Hite, 1984) indicated less than 10 to 270 ppb PCBs in the region near Area 9, while at other locations, PCBs were less than the detection level of 10 ppb (see Figure 38-1). Dieldrin, chlordane, DDT and pentachlorophenol were below the corresponding detection levels of 1, 5, 10 and 1 ppb.

Total PCB concentrations of 3.32 mg/kg were detected in Crab Orchard Lake sediments where the Area 9 Landfill drains into the lake (Ruelle, 1983). A June 15, 1983 U.S. FWS (Ruelle and Adams, April 1984) sampling program showed 0.41 and 0.76 ppm PCBs in Crab Orchard Lake sediments in the bay region off the Area 9 Landfill, while PCBs in three sediments from mid-lake, north of the Landfill, were below 0.05 ppm.

Bell, O'Toole and Stallings (1984) collected sediment samples from the Area 9 embayment of Crab Orchard Lake on June 21, 1984. Table 2-1 shows the analytical results for the dioxin and dibenzofuran analyses. Analyses for 2,3,7,8-TCDD, total tetra-CDD, penta-CDD and hexa-CDD in four sediments did not show detectable residues at the ppt detection limits employed. Hepta-CDD and octa-CDD, which are several orders of magnitude less toxic than the TCDD isomer, were detected at concentrations ranging from 160 to 1,400 and 3,400 to 12,000 ppt respectively. Among the dibenzofurans, only 2,3,7,8 tetra-CDF was found (50-210 ppt). An evaluation of the significance of these residues is discussed in Section 38.4, Crab Orchard Lake Environmental Effects. As addressed in that section, these concentrations in sediments were not found to represent a concern for humans or wildlife exposures.

The Illinois Department of Public Health (IPDH, 1976-1987) collected sediment samples from thirteen locations as part of ongoing monitoring studies at Crab Orchard Lake. Thirty one (31) lake sediment samples of those collected as part of this monitoring were analyzed for PCBs. The sediment samples for PCB analyses were obtained over a one year period between 1983 and 1984. Of these samples, twenty two were below the detection limit of 10 ug/kg, one sample from the Pigeon Creek bay area was slightly above the detection limit (11 ug/kg), and eight remaining sediments collected in the Area 9 embayment ranged from 13 to 270 ug/kg PCBs. No other concentrations of concern were detected in the analyses of indicators, metals and/or selected organic parameters in these sediments or in others collected during this monitoring period. No QA/QC data were provided to support these results.

TABLE 2-1

DIBENZO DIOXIN/FURAN ANALYSES OF CRAB ORCHARD FISH/SEDIMENTS

SAMPLES COLLECTED JUNE 21, 1984
ANALYZED BY CALIFORNIA ANALYTICAL LABORATORIES
(Bell, 8/8/84; O'Toole, 7/21/84; Stalling, 9/24/84)

SAMPLE NUMBER	SAMPLE DESCRIPTION	DIOXIN CONC. (ng/kg or ppt)						FURAN CONC. (ng/kg or ppt)						TOTAL EQUIVALENT CONCENTRATION (sum of detected residues) Sample Species Avg
		2378- TCDD	TOTAL TCDD	PENTA	HEXA	HEPTA	OCTA	2378- TCDF	TOTAL TCDF	PENTA	HEXA	HEPTA	OCTA	
	Toxicity Equivalent Factor (*)	1	1	0.5	0.04	0.001	0	0.1	0.1	0.1	0.01	0.001	0	
1024 E-1	Largemouth Bass	BDL	BDL	BDL	BDL	BDL	BDL	23	72	BDL	BDL	BDL	BDL	7.2
1024 E-10	Largemouth Bass	BDL	BDL	BDL	BDL	BDL	BDL	21	37	BDL	BDL	BDL	BDL	3.7
1024 E-2	Largemouth Bass	BDL	BDL	BDL	BDL	BDL	BDL	25	25	BDL	BDL	BDL	BDL	2.5
1024 E-3	Largemouth Bass	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	-- 4.5
1024 E-4	Channel Catfish	BDL	BDL	BDL	BDL	BDL	BDL	41	41	BDL	BDL	BDL	BDL	4.1
1024 E-5	Channel Catfish	BDL	BDL	23	BDL	180	BDL	BDL	BDL	BDL	BDL	BDL	BDL	11.7
1024 E-6	Channel Catfish	BDL	BDL	BDL	BDL	BDL	BDL	10	10	BDL	BDL	BDL	BDL	1.0 5.6
1024 E-7	Carp	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	--
1024 E-8	Carp	BDL	BDL	BDL	BDL	BDL	BDL	5.3	14	BDL	BDL	BDL	BDL	1.4
1024 E-9	Carp	BDL	BDL	BDL	BDL	BDL	BDL	27	27	BDL	BDL	BDL	BDL	2.7 2.1
FISH AVERAGE		BDL	BDL	5	BDL	21	BDL	16	24	BDL	BDL	BDL	BDL	4.3
1024 E-10	Sediment	BDL	BDL	BDL	BDL	160	3400	50	170	BDL	BDL	BDL	BDL	17.2
1024 E-10D	Sediment	BDL	BDL	BDL	BDL	200	3400	34	160	BDL	BDL	BDL	BDL	16.2
1024 E-11	Sediment	BDL	BDL	BDL	BDL	470	1200	BDL	BDL	BDL	BDL	BDL	BDL	0.47
1024 E-12	Sediment	BDL	BDL	BDL	BDL	880	11600	11	19	BDL	BDL	BDL	BDL	2.8
1024 E-13	Sediment	BDL	BDL	BDL	BDL	1400	12000	BDL	BDL	BDL	BDL	BDL	BDL	1.4
SEDIMENT AVERAGE		BDL	BDL	BDL	BDL	622	6320	59	110	BDL	BDL	BDL	BDL	7.6

(*) Assigned toxicity factor relative to 2,3,7,8-TCDD for estimation of risk levels.

USEPA (1987d). Interim Procedures for Estimating Risks Associated with
Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and Dibenzofurans.
Risk Assessment Forum, March, 1987.

BDL = below detection level of 3 ppt in tissue or 100 ppt in soil.

D = Duplicate Sample

2.7.2 Surface Water Analyses

In 1979 and 1980 (Illinois EPA, 1981), biological water quality sampling programs were conducted to assess the extent of the impact of wastewater discharge from the Marion Wastewater Treatment Plant (WWTP) to Crab Orchard Creek. Sampling points were located on a 5.5 mile stretch from the WWTP to Crab Orchard Lake. Crab Orchard Creek has a drainage area of 82.6 square miles and has a 7-day, 10-year low flow of 0 cfs. Crab Orchard Creek remains adversely affected by discharge from the Marion WWTP, with high levels of ammonia, nitrogen and phosphorus, and low dissolved oxygen levels (Illinois EPA, 1981).

On May 25-26, 1983 (Hite, 1984), fourteen (14) water samples from Crab Orchard Lake were analyzed for PCBs, chlorinated pesticides and metals. Figure 38-2 shows the sampling locations. PCBs (less than 0.1 ppb), chlordane (less than 0.01 ppb), DDT, endrin, methoxychlor, alpha-BHC, hexachlorobenzene and aldrin (less than 0.02 ppb) were all below the ppb detection levels, although the presence of dieldrin and chlordane was indicated.

While lead (less than 50 ppb), cadmium (less than 3 ppb), chromium, copper and cobalt (less than 5 ppb) were below ppb detection levels, barium and zinc concentrations ranged from 31 to 54 and from less than 50 to 101 ppb, respectively.

On May 2, 1984 (Hite, 1984), supplemental samples were collected from the same locations sampled in 1983, and were analyzed for the same parameters. Although the presence of PCBs, dieldrin, chlordane and pentachlorophenol was indicated, the concentrations of all these organics were below ppb detection levels, except at location #13, Area 9 Landfill embayment, which contained 0.16 ppb PCBs, and at #3 (southeast of Area

9) and #10 (North Lake) where 0.018 and 0.011 ppb pentachlorophenol, respectively, were measured. Figure 38-2 shows the detected PCB concentrations in water samples. All other constituents were within the drinking water standards with the exception of iron (0.4-3.2 mg/L), manganese (0.1 to 0.5 mg/L), and strontium (0.08 to 0.14 mg/L) (Hite, May 1984). Five (5) of the fourteen (14) sampling locations were near Area 9, while the others covered various regions of the lake.

IDPH (1976-1987) collected water samples from thirteen locations as part of ongoing monitoring studies at Crab Orchard Lake. Water samples are collected from selected sampling locations annually, but only twenty eight (28) samples collected during 1983 and 1984 were analyzed for PCBs. None of these samples contained detectable PCB concentrations (0.1 ug/L detection limit) with the exception of one sample adjacent to the Area 9 embayment which showed 0.16 ug/L. Additional water samples were taken during the monitoring program between 1976 to 1987 but these were analyzed for other parameters such as metals, indicators and/or selected organics not including PCBs. Some water samples exhibited concentrations of dissolved iron and manganese above the Illinois Water Supply and Federal Drinking Water Standards; however, these excursions do not represent a health risk since the criteria for iron and manganese are based on aesthetic concerns. No QA/QC data were provided to support these monitoring data.

2.7.3 Crab Orchard Lake Fish

A significant amount of data are available on several species of fish in Crab Orchard Lake. The species include largemouth bass, channel catfish, blue gill, white crappie, bullhead and carp. The majority of fish

samples collected at several locations in the lake had contaminant concentrations, when detectable, that were well below the Food and Drug Administration (FDA) limits.

Mercury levels in fish sampled in the summer of 1976 ranged from 0.13 to 0.46 ppm (Hite and King, 1977). Mercury levels were lower (less than 0.05 to 0.39 ppm) in samples collected in September 1982 (Ruelle, February 1983). These were all below the FDA action level of 0.5 ppm for mercury.

May 15, 1981 results (Frankland, 1984) from fifteen (15) fish samples revealed no mercury, dieldrin, DDT, heptachlor, or PCB contamination in fish.

Analysis of Crab Orchard Lake fish for PCBs in 1982 revealed whole-body concentrations exceeding 5 mg/kg (wet weight) in largemouth bass and channel catfish for three of twenty-five (25) fish samples (Ruelle, March 1983). The edible portions of the fish would not have been expected to contain PCB concentrations above 5.0 mg/kg. The fish sizes ranged from 1 lb. to 8.4 lbs.

In September 1982, thirteen (13) channel catfish and fourteen (14) largemouth bass were analyzed for lead and PCBs. Only one channel catfish had 0.14 ppm lead, while all others contained less than detectable concentrations (less than 0.1 ppm lead). PCBs in channel catfish ranged from less than 0.2 to 5.2 ppm, and in largemouth bass from 0.84 to 9.3 ppm (Ruelle, February 1983). The concentrations exceeding 5.0 mg/kg were detected with whole-body analyses; the edible portions of the fish might contain approximately one-third of this level.

In March 1983 (Paladino, 1983; Kenney, 1983), six (6) species of fish were sampled by the Illinois DOC for PCBs. The concentrations in

the edible portions of largemouth bass samples ranged from 0.12 to 0.34 ppm PCBs; in two (2) channel catfish, concentrations were 0.34 and 1.1 ppm PCBs; while carp had less than 0.01 to 0.02 ppm PCBs. No PCBs were detected in five (5) bluegill, five (5) white crappie or two (2) bullhead samples. These values are well within the previous FDA limit of 5 ppm PCBs and the current FDA limit of 2 ppm.

Fifteen (15) fish samples collected on April 16, 1984 and May 18, 1984 (Adams, May 30, 1984) were well below the FDA limits of 0.5 ppm for mercury (less than 0.01 to 0.36 ppm), 0.3 ppm for dieldrin (less than 0.01 to 0.12), 0.3 ppm for heptachlor (less than 0.01 to 0.16), 5 ppm for DDT (less than 0.01 ppm), and 2 ppm for PCBs (less than 0.1 to 1.1 ppm).

Analyses of four (4) largemouth bass, three (3) channel catfish, and three (3) carp samples on June 21, 1984 indicated that the six isomers of dioxins were below ppt detection levels. Tetra-CDF, which is significantly less toxic than 2,3,7,8 TCDD, ranged from 5.3 to 41 ppt. The other isomers of dibenzofurans were below detection levels (Bell, 1984).

Lead and pesticides have not impacted the fish population (Hite and King, 1977; Gritman, 1982).

As part of an ongoing monitoring program by the IDPH at Crab Orchard Lake, limited fish surveys including catfish, bass, carp and other species have been conducted since 1976 to the present (IDPH, 1976-1987). A total of 140 fish samples were analyzed for PCBs during this period. Fillet composites were analyzed for 73 of these samples (52 percent of the database). Approximately 76 percent of the samples were acquired from the east (east of Route 148) portion of the lake although

this area comprises only about 3 percent of the surface area of Crab Orchard Lake. During 1976, 42 fillet samples were analyzed for PCBs and all of these were below the 5 ppm FDA tolerance level at that time. Only three fish samples were collected between 1976 and 1983, and none of these was analyzed for PCBs. Between 1983 and 1987, 31 fillet samples were analyzed for PCBs and 28 of these (90 percent) were below the current FDA tolerance level of 2 ppm PCBs, effective since August 1983. The three samples above 2 ppm PCBs (2 catfish, 1 carp) were acquired from the eastern portion of the lake. No QA/QC support data were provided with these analyses. No distinct trends were discernible in the correlations between PCB concentrations as a function of time or sample size.

Table 2-2 presents a summary of the analytical data gathered for edible fish tissue as part of these ongoing studies by the State of Illinois. The table presents yearly averages computed for the different species included in the survey, the average size of the samples, and the number of data points available for computation of these averages. Samples taken from the western portion of the lake (near Carterville) show a general downward trend in the average PCB concentration with time. The averages for bluegill sunfish, bass, and bullhead were below 0.05 mg/kg for samples collected in 1987. Catfish and carp (one sample collected for each species) contained 0.41 mg/kg and 0.62 mg/kg PCBs, respectively, in 1987. The last (1987) sampling taken east of Highway 148 consisted mainly of one or two individual samples for each species. The sampling showed PCB concentrations of 0.16 mg/kg in sunfish, 0.21 mg/kg in bass, 0.21 mg/kg in bullhead, 0.53 mg/kg in crappie, 0.87 mg/kg in carp, and 4.5 mg/kg in catfish, all from the east end of the lake.

Kohler and Heidenger of the Fisheries Research Laboratory of Southern Illinois University (SIU) recently released preliminary findings of a continuing study on Crab Orchard Lake fish. Their studies focus on the seasonal and spatial patterns of PCB contamination in various fish species. Average PCB concentrations in edible tissue for fish samples collected in the fall of 1986 are presented in Table 2-3. A figure detailing the locations of the sampling could not be obtained, however, Sites 1 and 7 appear to be within the western portion of the lake, while Site 10 is located in the eastern part of the lake in the vicinity of the Area 9 Land-fill. The analytical detection limit used in the study was not reported, but might have been 0.1 mg/kg based on the data presented. The samples were collected as single fish grabs to correlate PCB concentrations with fish age. The study showed that, overall, 38 percent of fish sampled from the eastern part of the lake contained PCB concentrations above the FDA action level of 2.0 mg/kg; this compares to less than 4 percent of species found to exceed 2.0 mg/kg PCBs at Sites 1 and 7. As would be expected, bottom-feeding species such as carp and catfish contained higher levels of contaminants, and of these, the older species (and probably larger size) contained the highest concentration of PCBs.

2.7.4 Other Biota

Investigations of PCB contamination in deer tissue were conducted in 1982 (Ruelle, March 1983). Ten deer (male and female) between 0.5 to 3 years of age were hunted during the December 1982 season. There were no measurable PCB residues detected in either the fat or red meat deer tissues analyzed. Lead concentrations, however, averaged 5.59 ppm dry weight, (max. 13 ppm) in deer livers analyzed in 1980 (Gritman, 1982).

TABLE 2-2

FISH MONITORING DATA SUMMARY
Illinois Interagency Program by IDOC, IEPA & IDPH
for
CRAB ORCHARD LAKE, MARION, ILLINOIS

SPECIES	DATE COLLECTED	YEARLY AVG PCB CONC. (Filet) mg/kg ww	NUMBER OF SAMPLES	AVERAGE SAMPLE WEIGHT lb
<u>WEST LAKE</u>				
CATFISH	1976	2.00	5	5.0
	1987	0.44	1	3.3
CARP	1976	0.91	5	2.8
	1985	< 0.05	2	2.5
	1987	0.62	1	3.0
* LARGE MOUTH BASS	1976	0.14	7	2.6
	1985	< 0.05	1	2.8
	1987	< 0.05	1	2.9
BULLHEAD	1976	0.55	2	0.6
	1985	< 0.05	1	0.6
BLUEGILL SUNFISH	1976	< 0.05	2	0.2
<u>EAST LAKE</u>				
CATFISH	1976	2.85	3	5.4
	1985	0.59	3	7.7
	1986	3.20	2	3.6
	1987	4.50	1	7.8
CARP	1976	1.75	5	2.7
	1985	1.85	6	3.3
	1986	0.71	4	4.0
	1987	0.87	2	1.9
LARGE MOUTH BASS	1976	0.45	7	2.7
	1985	0.25	3	2.8
	1986	0.60	2	2.4
	1987	0.21	1	1.6
BULLHEAD	1976	0.39	4	0.7
	1986	0.21	2	1.1
BLUEGILL SUNFISH	1976	0.16	2	0.3
CRAPPIE	1983	0.53	1	0.2

Samples with results below the analytical detection level are calculated as half the detection limit or 0.05 mg/kg.

Table 2-3

Mean PCB concentrations (ppm) in fillets of various species
collected from three sites in Crab Orchard Lake Fall 1986.

Species/Age Group ^a	Site		
	1	7	10
Largemouth bass			
Young	0.126 (0) ^b	0.142 (0)	1.81 (33)
Intermediate	0.226 (0)	0.332 (0)	1.61 (33)
Old	0.222 (0)	0.356 (0)	1.50 (33)
Composite	0.191 (0)	0.271 (0)	1.64 (33)
Channel catfish			
Young	0.201 (0)	0.339 (0)	0.903 (0)
Intermediate	3.46 (66)	1.00 (0)	2.20 (50) ^c
Old	0.798 (0)	1.47 (33)	5.37 (100)
Composite	1.49 (22)	0.939 (11)	2.90 (50)
Common Carp			
Young	0.457 (0)	0.133 (0)	2.69 (100)
Intermediate	0.790 (0)	0.281 (0)	10.3 (100)
Old	0.510 (0)	0.285 (0)	3.76 (69)
Composite	0.586 (0)	0.233 (0)	5.59 (89)
Bluegill			
Young	0.269 (0)	0.155 (0)	1.65 (33)
Intermediate	0.216 (0)	0.244 (0)	1.89 (33)
Old	0.114 (0)	0.164 (0)	1.22 (0)
Composite	0.200 (0)	0.181 (0)	1.58 (22)
White Crappie			
Young	0.148 (0)	0.107 (0)	0.200 (0)
Intermediate	0.157 (0)	0.141 (0)	0.349 (0)
Old	0.153 (0)	0.172 (0)	0.243 (0)
Composite	0.153 (0)	0.140 (0)	0.264 (0)
Gizzard shad			
Young	0.388 (0)	0.396 (0)	0.973 (0)
Intermediate	0.323 (0)	0.738 (0)	3.28 (100)
Old	0.218 (0)	0.334 (0)	0.486 (0)
Composite	0.309 (0)	0.490 (0)	1.58 (33)

^a/n = 3 unless other wise noted.

^b/n = Percentage of specimens ≥ FDA action level (2.00 ppm).

^c/n = 2

Source: Kohler and Heidenger, SIU, Undated.

JA: 107:007

A larger study (Woolf, 1983) presented 1980-81 data for nine heavy metals in livers of 441 white-tailed deer in 26 Illinois counties. Mean concentrations (in ppm, wet weight) observed at Crab Orchard Refuge were: 0.43 cadmium, 0.36 cobalt, 3.1 chromium, 115 copper, 211 magnesium, 8.4 manganese, 4.5 nickel, 5.6 lead and 69 zinc.

In July 1982, lead levels were measured in earthworms, honeysuckle roots and leaves, prairie vole liver, and white-footed mouse liver. The highest lead levels (1.73 and 4.19 ppm) were detected in earthworms from the Fire Station dumps. Earthworms at the Area 9 Landfill, Water Tower dump and U.S. Powder contained less than 0.6, 0.49, less than 0.2 and 0.52 ppm lead, respectively. Honeysuckle roots and leaves had lead levels less than 0.46 ppm, except for one root sample from the Area 9 Landfill, which contained 81.6 ppm lead. Lead was less than 0.28 ppm in prairie vole livers and white-footed mouse livers at all the sampling sites (Ruelle, February 1983).

2.7.5 Soil Samples

A number of previous investigations have provided soil sampling and analysis results near suspected source areas around the Refuge. The results from previous soil investigations are discussed in the individual sections of this report. Previous investigations have covered the Area 9 Landfill and Plant sites, the Water Tower Landfill, the Fire Station Landfill, and the Job Corps site, as well as the Carterville Hunting Area, the Hampton Cemetery (HC) dump, the Area 10 dump and the U.S. Powder dump. These latter four sites were not included in this RI/FS. The previous PCB analytical results from these sites indicated the following ranges (Ruelle and Adams, 1984) : Hampton Cemetery (4

samples less than 0.05 ppm); Area 10 soils (less than 0.05 to 0.24 ppm); U.S. Powder soils (less than 0.05 to 2.5 ppm).

Lead concentrations in soils were measured during June 27 - July 1, 1982 (Ruelle, February 1983). The Fire Station, Water Tower and Hampton Cemetery dumps showed elevated levels of lead as given below, while the other sites had lead levels similar to controls (13-35 ppm). Carterville Hunting Area and Area-13 had elevated levels of arsenic (4.8 - 23 and 6.1 - 15 ppm, respectively). It has been speculated that arsenic and lead concentrations may be elevated throughout the Refuge due to repeated spraying of lead arsenate during the early 1940s to control insects. (Redmon, 1983).

<u>Samples</u>	<u>F.S.</u>	<u>Lead (ppm)</u>	<u>H.C.</u>
		<u>W.T.</u>	
Surface, center	108	86.3	151
1' depth, center	553.	843	11.5
Surface, edge	70.5	52.3	20.4
1' depth, edge	141	19.8	30.3

On June 15, 1983, surface and 1-ft deep samples from the Water Tower, Hampton Cemetery, U.S. Powder and Area-10 were analyzed for PCBs and metals (Ruelle, July 1984). PCBs were not detected in the Hampton Cemetery dump, while low levels of PCBs were measured in Area-10 (0.07 - 0.24 ppm) and the Water Tower dump (LT 0.05 - 0.15 ppm). U.S. Powder had higher levels (LT 0.05 - 2.5 ppm) of PCBs. Heavy metals, including lead and zinc, in soils from Water Tower, Hampton Cemetery and Area-10 dumps were within southern Illinois background, and U.S. Powder soils had lead concentrations of 11 to 130 ppm.

Three samples from Area-11 refuse collected September 18, 1984 (Hickins, 1984) had no detectable PCBs or chlorinated pesticides, but appeared to contain some polysulfones.

The limited data on the Water Tower, Fire Station and other areas suggested that PCBs, lead, zinc and arsenic may be found elsewhere on the Refuge dump sites. Additional data on these sites were generated as part of this RI/FS.

2.8 Initial Remedial Measures

The FWS removed and disposed of five (5) million pounds of explosives and other refuse from various locations on the Refuge between 1973 and 1983 (Redmon, 1983). Otherwise, remedial action has been limited to Site 32, the Area 9 Landfill. The Illinois EPA sealed off the Area 9 Landfill in 1984 after determining that it contained PCBs and heavy metal constituents (Carlson, 1984). A chain link fence was installed by the FWS around the Area 9 Landfill in 1984. Also in 1984, the tenant of buildings in Area 9 restricted access to several buildings and areas after PCBs were detected in nearby soils (Adams, 1984).

SECTION 3 - SITE SAMPLING PLAN

3.1 Objectives

The Site Sampling Plan (SSP) was developed as part of the RI/FS Work Plan dated June 1985. The SSP specified the sampling locations, procedures and practices that were to be used for the RI program at the Crab Orchard Refuge.

Site sampling was performed in two phases. The purpose of Phase I was to screen broad areas to determine if potential problems existed at a given site and to define the chemical compounds contributing to the problem. Phase I included geophysical surveys, hydrogeologic investigations, and a screening of each site to determine the type of contaminants present. Monitoring wells were installed, but ground water samples were not collected until Phase II.

The Phase II sampling program was based on the screening results generated in Phase I. Phase II consisted of additional sampling and analyses to supplement and verify the data obtained previously and to better define the extent of contamination at those sites where contamination had been detected. Due to the costs associated with EPA's Contract Laboratory Procedures (CLP), Phase I investigations were generally limited to screening parameters to determine which samples should be analyzed in Phase II in accordance with the full CLP protocols.

The approach used in developing the SSP is discussed in the following sections. These sections address the sample types collected, sample locations, depths, analytical parameters, and basis for selection. References are made to previous reports prepared by O'Brien & Gere as part of the RI/FS program. These reports include:

- RI/FS Work Plan (June 1985),

- RI/FS Work Plan Supplements (Phase I, December 1985, and Phase II, November 1986),
- RI/FS Quality Assurance Project Plan, or QAPP (November 1986).

3.2 Sample Types and Locations

3.2.1 Sample Types

Various matrices were sampled as part of the RI:

1. Surface Water: including streams, raw and finished water supplies, pond waters and waters from Crab Orchard Lake.
2. Ground Water: samples from monitoring wells were collected during Phase II.
3. Sediment: from streams, ponds and Crab Orchard Lake.
4. Soil: including soils potentially affected by surface spillage and fill material from sites of past disposal activity.
5. Air: as part of the Site Safety Program.
6. Biota: fish including bass, bullhead, catfish and carp.

Most soil and water samples were obtained as single grab samples. In Phase I, most samples consisted of areal soil and/or water composites of several grab samples in order to scan a wide area. Most of the Phase II samples were collected as distinct grabs of soil and water samples to better define the areas of contamination. Phase II also included many areal composites as well, but typically these defined a smaller area than the Phase I composites. Fish samples were usually collected as single species composites consisting of the edible portions of two to five fish. Specific sampling and compositing procedures were discussed in Section 4 and Attachment 3 of the QAPP (O'Brien & Gere, November 1986).

3.2.2 Sampling Locations

Phase I sampling locations were established during a site reconnaissance visit on March 26-28, 1985. The factors considered in the selection of sample location, depth, and analytical parameters were addressed in the Work Plan and Site Operations Plan. A brief summary of that information is included in Section 3.4 of this Report.

Phase II sampling locations were selected based on the analytical results obtained from Phase I. For example, soil samples were collected at greater depths and in the areas surrounding any locations identified as a concern based on the data from Phase I. Surface and ground waters were sampled in the general areas identified as potentially contaminated based on the Phase I investigation. The sampling locations were identified on site maps which included distances from numbered field reconnaissance stakes and other landmarks. All sampling locations were photographed.

3.3 Analytical Parameters

Due to the high costs and delays associated with CLP organics analyses, the Phase I sampling program utilized a broad screening program to determine which sample locations should be subsequently resampled and analyzed in Phase II using the complete CLP protocol. Generally, the screening analyses were conducted using a higher detection level to determine which compounds may be present. Based on the screening, samples were selected for full analyses to determine the concentrations of parameters at a lower detection level. The analytical program is described in detail in the QAPP document as well as in Appendix A to the Work Plan. This approach allowed the sites to be screened over a wide area for locations of concern and provided broad chemical characterization in a cost-effective manner.

3.3.1 Phase I Analyses

Analytical parameter sets for the various samples collected during the Phase I sampling efforts are presented in Table 3-1. The factors for selection of the analytical parameters for Phase I were described in Attachment S-3 of the Work Plan Supplement of December 1985. The following summary table illustrates the purpose and organization by analytical sets for Phase I and specifies the sites where each was applied. A complete listing of the chemical compounds for each analytical set for Phase I is shown on Table 3-3.

<u>Anal. Set</u>	<u>Sites</u>	<u>Purpose</u>
A	All	Screens for presence of toxic organics and quantifies all other parameters (ICP metals, cyanide, indicators, explosives, nitrogen and phosphorus) but PCDF/PCDD.
B	32, 33	Quantifies only PCB concentrations.
C	32	Determines spatial distribution of PCBs and PCDF/PCDD in landfill cores in addition to indicators and nitrogen in soil.
D	All	Screens for presence of organic priority pollutants and PCDF/PCDD in addition to phosphorus, nitrogen, indicators, cyanide, explosives and ICP metals.
E	34	Quantifies constituents subject to primary and secondary drinking water parameters.
F	All	Verifies and quantifies priority pollutants in samples screened by Set A.
G	All	Verifies and quantifies priority pollutants and PCDF/PCDD in samples screened by D.
H	32, 33	Quantifies priority pollutants and PCDF/PCDD in samples which were not previously screened; other soil characteristics as defined for Set D.

TABLE 3-1 (page 1 of 1)

PARAMETER LIST FOR PHASE I ANALYSIS SETS
 (See Table 3-3 for List of Compounds within each parameter group)

PARAMETERS	ANALYSIS SET							
	A	B	C	D	E	F	G	H
1. Purgeable Priority Pollutants								
-Screen	X	-	-	X	-	-	-	-
-Full Anal.	-	-	-	-	-	X	X	X
2. Acid Extract. Priority Pollutants								
-Screen	X	-	-	X	-	-	-	-
-Full Anal.	-	-	-	-	-	X	X	X
3. Base/Neutral Extract. Prior. Poll.								
-Screen	X	-	-	X	-	-	-	-
-Full Anal.	-	-	-	-	-	X	X	X
4. Pesticide/PCB Priority Pollutants								
-Screen	X	-	-	X	-	-	-	-
-Full Anal.	-	-	-	-	-	X	X	X
5. Polychlorinated Biphenyls								
	-	X	X	-	-	-	-	-
6. Metals - ICP Scan								
- Prior. Poll. Metals by AA	X	-	-	X	-	-	-	-
- Mercury	-	-	-	-	-	-	-	X
	X	-	-	X	-	-	-	-
7. EP Toxicity Metals								
	-	-	-	-	-	-	-	-
8. Cyanide								
	X	-	-	X	-	-	-	X
9. Indicators - pH (field)								
- Specific Conductance (field)	X	-	X	X	-	-	-	X
- Total Organic Carbon	X	-	X	X	-	-	-	X
- Total Organic Halogen	X	-	X	X	-	-	-	X
10. Explosives Residues by HPLC								
	X	-	-	X	-	-	-	X
11. Nitrogen Series: TN04, NH3, NO3								
	X	-	X	X	-	-	-	X
12. PCDD/PCDF								
-Screen	-	-	X	X	-	-	-	-
-Full Anal.	-	-	-	-	-	-	X	X
13. Cation Exchange Capacity								
	-	-	X	-	-	X	X	-
14. Total Phosphorus								
	X	-	-	X	-	-	-	X
15. Primary & Secondary Drinking Water Parameters								
	-	-	-	-	X	-	-	-
16. Percent Solids (on soil/sed only)								
	X	X	X	X	-	X	X	X

NOTE: SETS F & G are full analysis of parameters screened in SETS A & D resptly.

SET H is full analysis of selected samples instead of SET D

TABLE 3-2 (page 1 of 2)

PARAMETER LIST FOR PHASE II ANALYSIS SETS
(See Table 3-4 for List of Compounds within each parameter group)

PARAMETERS	ANALYSIS SET															
	B	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1. CLP HSL Full Analysis	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	X
2. CLP HSL Volatiles	-	-	-	-	X	X	-	-	-	-	-	X	-	X	-	-
3. CLP HSL Base/Neut/Acids	-	X	X	-	X	-	-	-	-	-	-	-	-	X	-	-
4. Nitrosamines (CLP, soil)	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
5. Nitrosamines (low level)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
6. CLP HSL Pesticide/PCB	-	X	-	-	-	X	-	-	-	-	-	X	X	-	-	-
7. PCBs General	X	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
8. PCBs Low Level (water)	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	X
9. PCBs Semi-low (sediment)	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-	-
10. Metals - CLP HSL	-	X	-	-	-	X	-	-	-	-	-	X	-	X	-	X
11. Metals - NIPDMR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. Special - Mercury	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-
- Cadmium	-	-	-	-	-	X	-	-	X	X	X	-	X	X	X	X
- Chromium	-	-	-	-	-	X	X	-	-	-	X	-	-	X	-	X
- Magnesium	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
- Lead	-	-	-	-	-	X	-	X	X	X	X	-	X	X	X	X
- Arsenic	-	-	-	-	-	X	-	X	-	-	-	-	-	X	X	X
- Copper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
13. EP Toxicity - Cr	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
- Cd, Cr, Pb	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
14. Cyanide	-	X	X	X	-	-	-	-	-	-	X	X	-	X	-	X
15. Indicators - pH	-	X	X	-	X	X	X	X	-	X	X	X	-	X	X	X
- NH3, NO3, F	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X
16. Explosives by HPLC	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X
17. Lipids	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-
18. PCDD/PCDF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19. Total Phosphorus	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
20. Grain Size	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X
21. Percent Solids(soil/sed)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

NOTE: Well water metals analyses include unfiltered and filtered

TABLE 4-4

HYDRAULIC CONDUCTIVITY VALUES

<u>Well #</u>	<u>Date</u>	<u>Ft/Sec</u>	<u>Cm/Sec</u>
15-4	6/18/87	1.63×10^{-6} ft/sec.	5.03×10^{-5} cm/sec.
17-8	1/20/87	4.96×10^{-5} ft/sec.	1.51×10^{-3} cm/sec.
17-9	1/20/87	1.06×10^{-5} ft/sec.	3.20×10^{-4} cm/sec.
17-10	1/20/87	2.20×10^{-4} ft/sec.	6.72×10^{-3} cm/sec.
17-11	1/20/87	1.50×10^{-6} ft/sec.	4.58×10^{-5} cm/sec.
17-65	1/20/87	2.64×10^{-4} ft/sec.	8.07×10^{-3} cm/sec.
22-8	1/19/87	1.63×10^{-5} ft/sec.	2.00×10^{-4} cm/sec.
28-7	1/20/87	5.02×10^{-6} ft/sec.	1.55×10^{-5} cm/sec.
28-8	1/20/87	1.95×10^{-6} ft/sec.	6.01×10^{-6} cm/sec.
28-15	1/20/87	2.48×10^{-7} ft/sec.	7.58×10^{-6} cm/sec.
28-16	1/21/87	5.93×10^{-6} ft/sec.	1.81×10^{-4} cm/sec.
29-8	1/19/87	6.16×10^{-5} ft/sec.	1.90×10^{-3} cm/sec.
29-9	1/20/87	4.87×10^{-6} ft/sec.	1.50×10^{-4} cm/sec.
29-10	1/20/87	1.77×10^{-6} ft/sec.	5.46×10^{-5} cm/sec.
29-11	1/19/87	4.05×10^{-6} ft/sec.	1.25×10^{-4} cm/sec.
32-2	6/18/87	6.63×10^{-6} ft/sec.	2.04×10^{-4} cm/sec.
32-2	6/18/87	2.54×10^{-6} ft/sec.	7.83×10^{-5} cm/sec.
32-61 (COW3)	1/21/87	6.22×10^{-6} ft/sec.	1.92×10^{-4} cm/sec.
32-62 (COW2)	1/21/87	5.20×10^{-7} ft/sec.	1.60×10^{-5} cm/sec.
32-63	1/21/87	2.32×10^{-6} ft/sec.	7.16×10^{-5} cm/sec.
32-109	1/21/87	4.00×10^{-6} ft/sec.	1.23×10^{-4} cm/sec.
32-110	--	**	**
33-340	1/21/87	9.36×10^{-7} ft/sec.	2.86×10^{-5} cm/sec.
33-341	1/21/87	2.50×10^{-5} ft/sec.	7.68×10^{-4} cm/sec.
33-342	1/21/87		

* Data uninterpretable due to erratic water level readings.

** Artesian condition and well head construction design inhibited permeability testing.

TABLE 3-2 (page 2 of 2)

PARAMETER LIST FOR PHASE II ANALYSIS SETS
(See Table 3-4 for List of Compounds within each parameter group)

PARAMETERS	ANALYSIS SET (contd.)															
	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	
1. CLP HSL Full Analysis	X	-	-	-	-	-	X	-	-	X	X	X	-	X	-	
2. CLP HSL Volatiles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
3. CLP HSL Base/Neut/Acids	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	
4. Nitrosamines (CLP, soil)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
5. Nitrosamines (low level)	X	-	-	-	-	-	-	-	-	X	-	-	-	X	X	
6. CLP HSL Pesticide/PCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
7. PCBs General	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	
8. PCBs Low Level (water)	X	-	-	-	-	-	-	-	-	X	-	-	-	X	X	
9. PCBs Semi-low (sediment)	-	-	-	-	-	X	X	-	X	-	X	-	-	-	-	
10. Metals - CLP HSL	X	-	-	-	-	-	-	-	-	X	X	X	-	-	-	
11. Metals - NIPDMR	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	
12. Special - Mercury	-	-	-	-	-	-	-	X	-	-	-	-	X	-	X	
- Cadmium	X	-	X	-	-	-	-	-	-	X	-	-	-	-	X	
- Chromium	X	-	X	-	-	-	-	X	-	X	-	-	-	-	X	
- Magnesium	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	
- Lead	X	-	-	-	X	X	X	X	X	X	-	-	-	-	X	
- Arsenic	X	-	-	-	X	-	-	-	-	X	-	-	-	-	X	
- Copper	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	
13. EP Toxicity - Cr	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
- Cd, Cr, Pb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
14. Cyanide	X	-	X	X	X	-	-	-	-	X	X	-	-	X	X	
15. Indicators - pH	X	-	-	-	-	X	X	-	-	X	X	-	-	X	X	
- NO ₂ , NO ₃ , F	X	-	-	-	-	-	-	-	-	X	-	-	-	-	X	
16. Explosives by HPLC	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	
17. Lipids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
18. PCDD/PCDF	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	
19. Total Phosphorus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
20. Grain Size	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	
21. Percent Solids(soil/sed)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

NOTE: Well water metals analyses include unfiltered and filtered

LIST OF CHEMICAL COMPOUNDS FOR PARAMETERS IN TABLE 3-1
(for PHASE I, completed November 1985)

PURGEABLE PRIORITY POLLUTANTS

1 Chloroethane	15 1,2-Dichloropropane	29 1,1 Dichloroethylene
2 Bromoethane	16 t-1,3-Dichloropropane	30 t-1,2-Dichloroethylene
3 Dichlorodifluoroethane	17 Trichloroethane	31 Bromochloroethane
4 Vinyl chloride	18 Benzene	32 Trichloroethylene
5 Chloroethane	19 Dibromochloroethane	33 2-Bromo-1-chloropropane
6 Methylene Chloride	20 1,1,2-Trichloroethane	34 Tetrachloroethylene
7 Trichlorofluoroethane	21 c-1,3-Dichloropropane	35 Acetone
8 1,1-Dichloroethane	22 2-Chloroethylvinyl ether	36 Carbon disulfide
9 1,1-Dichloroethane	23 Bromoform	37 2-Butanone
10 t-1,1-Dichloroethane	24 1,1,2,2-Tetrachloroethane	38 Vinyl acetate
11 Chloroform	25 Tetrachloroethane	39 2-Hexanone
12 1,1,1-Trichloroethane	26 Toluene	40 4-Methyl-2-pentanone
13 Carbon tetrachloride	27 Chlorobenzene	41 Styrene
14 Bromodichloroethane	28 Ethylbenzene	42 Total xylenes

ACID EXTRACTABLE PRIORITY POLLUTANTS

1 Phenol	6 2-Nitrophenol	11 Pentafluorophenol
2 o-Phenol	7 4-Nitrophenol	12 2,4,6-Trichlorophenol
3 2-Fluorophenol	8 4-Chloro-3-methylphenol	13 2-Methyl-4,6-dinitrophenol
4 2,4-Dimethylphenol	9 2,4-Dichlorophenol	14 Pentachlorophenol
5 2-Chlorophenol	10 2,4-Dinitrophenol	

BASE/NEUTRAL PRIORITY POLLUTANTS

1 1,3-Dichlorobenzene	17 Acenaphthene	33 Benzidine
2 1,4-Dichlorobenzene	18 Dimethyl phthalate	34 Butyl benzyl phthalate
3 1,2-Dichlorobenzene	19 2,6-Dinitrotoluene	35 Bis (2-ethylhexyl) phthalate
4 Hexachloroethane	20 Fluorene	36 Chrysene
5 Bis (2-chloroethyl) ether	21 4-Chlorophenyl phenyl ether	37 Benzo(a)anthracene
6 Bis (2-chloroisopropyl) ether	22 2,4-Dinitrotoluene	38 3,3-Dichlorobenzidine
7 N-Nitrosodi-n-propylamine	23 1,2-Diphenylhydrazine	39 Di-n-octylphthalate
8 Nitrobenzene	24 Diethylphthalate	40 Benzo(b)fluoranthene
9 Hexachlorobutadiene	25 N-nitrosodiphenylamine	41 Benzo(k)fluoranthene
10 1,2,4-Trichlorobenzene	26 Hexachlorobenzene	42 Benzo(a)pyrene
11 Isophorone	27 4-Bromophenyl phenyl ether	43 Indeno(1,2,3-cd)pyrene
12 Naphthalene	28 Phenanthrene	44 Dibenzo(a,h)anthracene
13 Bis (2-chloroethoxy) methane	29 Anthracene	45 Benzo(g,h,i)perylene
14 Hexachlorocyclopentadiene	30 Di-n-butyl phthalate	46 N-Nitrosodimethyl Amine
15 2-Chloronaphthalene	31 Fluoranthene	
16 Acenaphthalene	32 Pyrene	

PESTICIDES/PCB PRIORITY POLLUTANTS

1 Alpha-BHC	10 Dieldrin	19 Toxaphene
2 Gamma-BHC (Lindane)	11 Endrin	20 Arochlor-1016
3 Beta-BHC	12 4,4'-DDD	21 Arochlor-1242
4 Delta-BHC	13 Endosulfan II	22 Arochlor-1221
5 Heptachlor	14 4,4'-DDT	23 Arochlor-1232
6 Aldrin	15 Endosulfan Sulfate	24 Arochlor-1248
7 Heptachlor epoxide	16 Endrin Aldehyde	25 Arochlor-1254
8 Endosulfan I	17 Methoxychlor	26 Arochlor-1260
9 4,4'-DDE	18 Chlordane	27 Endrin ketone

TABLE 3-3 (page 2 of 2)

LIST OF CHEMICAL COMPOUNDS FOR PARAMETERS IN TABLE 3-1
(for PHASE I, completed November 1985)

PCDDs/PCDFs

- 1 Tetra-CDD
- 2 Penta-CDD
- 3 Hexa-CDD
- 4 Hepta-CDD

- 5 Octa-CDD
- 6 Tetra-CDF
- 7 Penta-CDF
- 8 Hexa-CDF

- 9 Hepta-CDF
- 10 Octa-CDF

EXPLOSIVES RESIDUES BY HPLC

- 1 HMX
- 2 RDX
- 3 1,3,5 TNB

- 4 1,3 DNB
- 5 NB
- 6 TETRYL

- 7 2,4,6 TNT
- 8 2,6 DNT
- 9 2,4 DNT

METALS (ICPs AND PP ATOMIC ABS.)

- 1 Aluminum
- 2 Antimony
- 3 Arsenic
- 4 Barium
- 5 Cadmium
- 6 Calcium
- 7 Chromium
- 8 Cobalt
- 9 Copper

- 10 Iron
- 11 Lead
- 12 Magnesium
- 13 Manganese
- 14 Molybdenum
- 15 Mercury
- 16 Nickel
- 17 Potassium
- 18 Selenium

- 20 Silver
- 21 Sodium
- 22 Tin
- 23 Titanium
- 24 Vanadium
- 25 Zinc

OTHERS

INDICATORS

- 1 pH
- 2 Specific Conductivity
- 3 Total Organic Carbon
- 4 Total Organic Halides

NITROGEN SERIES

- 1 Ammonia Nitrogen
- 2 Nitrate Nitrogen
- 3 Nitrite Nitrogen
- 4 Total Kjeldahl Nitrogen

CYANIDE

CATION EXCHANGE CAPACITY

TOTAL PHOSPHORUS

PRIMARY & SECONDARY DRINKING WATER STANDARDS (40 CFR 143)

Primary Inorganic Chemicals

- 1 Arsenic
- 2 Barium
- 3 Cadmium
- 4 Chromium
- 5 Fluoride
- 6 Lead
- 7 Mercury
- 8 Nitrate
- 9 Silver

Secondary Inorganic Chemicals

- 1 Chloride
- 2 Copper
- 3 Iron
- 4 Manganese
- 5 Sodium
- 6 Sulfate
- 7 Zinc
- 8 Corrosivity

Organic Chemicals

- 1 Endrin
- 2 Lindane
- 3 Methoxychlor
- 4 Toxaphene
- 5 2,4-D
- 6 2,4,5-TP Silver

TABLE 3-4 (page 1 of 2)

LIST OF CHEMICAL COMPOUNDS FOR PARAMETERS IN TABLE 3-2
(for PHASE II, completed December 1986)

CLP HSL VOLATILES		
1 Chloroethane	13 Dibromochloroethane	25 Toluene
2 Bromoethane	14 1,2-Dichloropropane	26 Chlorobenzene
3 t-1,2-Dichloroethane	15 t-1,3-Dichloropropane	27 Ethylbenzene
4 Vinyl chloride	16 Trichloroethane	28 Carbon Disulfide
5 Chloroethane	17 Benzene	29 1,2-Dichloroethane
6 Methylene Chloride	18 Dibromochloroethane	30 Acetone
7 Styrene	19 1,1,2-Trichloroethane	31 2-Butanone
8 1,1-Dichloroethane	20 c-1,3-Dichloropropane	32 Vinyl acetate
9 1,1-Dichloroethane	21 2-Chloroethylvinyl ether	33 2-Hexanone
10 Chloroform	22 Bromoform	34 4-Methyl-2-pentanone
11 1,1,1-Trichloroethane	23 1,1,2,2-Tetrachloroethane	35 Total xylenes
12 Carbon tetrachloride	24 Tetrachloroethane	36 Total xylenes

HSL CLP BASE/NEUTRAL/ACID EXTRACTABLES (SEMI-VOLATILES)		
1 Phenol	23 1,2,4-Trichlorobenzene	45 Pyrene
2 2-Methylphenol	24 Isophorone	46 Butyl benzyl phthalate
3 2,4-Dimethylphenol	25 Naphthalene	47 Bis (2-ethylhexyl) phthalate
4 2-Chlorophenol	26 Bis (2-chloroethoxy) methane	48 Chrysene
5 2-Nitrophenol	27 Hexachlorocyclopentadiene	49 Benzo(a)anthracene
6 4-Chloro-3-methylphenol	28 2-Chloronaphthalene	50 3,3-Dichlorobenzidine
7 2,4-Dichlorophenol	29 Acenaphthalene	51 Di-n-octylphthalate
8 2,4-Dinitrophenol	30 Acenaphthene	52 Benzo(b)fluoranthene
9 2,4,5-Trichlorophenol	31 Dimethyl phthalate	53 Benzo(k)fluoranthene
10 2,4,6-Trichlorophenol	32 2,6-Dinitrotoluene	54 Benzo(a)pyrene
11 2-Methyl-4,6-dinitrophenol	33 Fluorene	55 Indeno(1,2,3-cd)pyrene
12 Pentachlorophenol	34 4-Chlorophenyl phenyl ether	56 Dibenzo(a,h)anthracene
13 4-Methylphenol	35 2,4-Dinitrotoluene	57 Benzo(g,h,i)perylene
14 1,3-Dichlorobenzene	36 2-Methylnaphthalene	58 2-Nitroaniline
15 1,4-Dichlorobenzene	37 Diethylphthalate	59 3-Nitroaniline
16 1,2-Dichlorobenzene	38 N-nitrosodiphenylamine	60 4-Nitroaniline
17 Hexachloroethane	39 Hexachlorobenzene	61 4-Chloroaniline
18 Bis (2-chloroethyl) ether	40 4-Bromophenyl phenyl ether	62 Benzyl Alcohol
19 Bis (2-chloroisopropyl) ether	41 Phenanthrene	63 Benzoic Acid
20 N-Nitrosodi-n-propylamine	42 Anthracene	64 Dibenzofuran
21 Nitrobenzene	43 Di-n-butyl phthalate	
22 Hexachlorobutadiene	44 Fluoranthene	

CLP HSL PESTICIDES/PCB		
1 Alpha-BHC	10 Dieldrin	19 Arochlor-1016
2 Gamma-BHC (Lindane)	11 Endrin	20 Arochlor-1242
3 Beta-BHC	12 4,4'-DDD	21 Arochlor-1221
4 Delta-BHC	13 Endosulfan II	22 Arochlor-1232
5 Heptachlor	14 4,4'-DDT	23 Arochlor-1248
6 Aldrin	15 Endosulfan Sulfate	24 Arochlor-1254
7 Heptachlor epoxide	16 Methoxychlor	25 Arochlor-1260
8 Endosulfan I	17 Chlordane	26 Endrin ketone
9 4,4'-DDE	18 Toxaphene	

TABLE 3-4 (page 2 of 2)

LIST OF CHEMICAL COMPOUNDS FOR PARAMETERS IN TABLE 3-2
(for PHASE II, completed December 1986)

PCDDs/PCDFs		
1 Tetra-CDD	5 Octa-CDD	9 Hepta-CDF
2 Penta-CDD	6 Tetra-CDF	10 Octa-CDF
3 Hexa-CDD	7 Penta-CDF	
4 Hepta-CDD	8 Hexa-CDF	
EXPLOSIVES RESIDUES BY HPLC		
1 HMX	4 1,3 DNB	7 2,4,6 TNT
2 RDX	5 NB	8 2,6 DNT
3 1,3,5 TNB	6 TETRYL	9 2,4 DNT
CLP HSL METALS		
1 Aluminum	9 Cobalt	17 Potassium
2 Antimony	10 Copper	18 Selenium
3 Arsenic	11 Iron	19 Silver
4 Barium	12 Lead	20 Sodium
5 Beryllium	13 Magnesium	21 Thallium
6 Cadmium	14 Manganese	22 Vanadium
7 Calcium	15 Mercury	23 Zinc
8 Chromium	16 Nickel	
NATIONAL INTERIM PRIMARY DRINKING WATER PARAMETERS (40CFR 141)		
1 Arsenic	4 Chromium	7 Selenium
2 Barium	5 Lead	8 Silver
3 Cadmium	6 Mercury	
OTHERS		
INDICATORS	NITROGEN SERIES	CYANIDE
1 pH	1 Ammonia Nitrogen	FLUORIDE
2 Percent solids	2 Nitrate Nitrogen	TOTAL PHOSPHORUS
	3 Nitrite Nitrogen	

3.3.2 Phase II Analyses

Preliminary assessments of risk were developed from Phase I data to assist in the selection of sites that required additional investigation. The list of analytical sets (Table 3-2) for Phase II was revised from that used in Phase I (Table 3-1), to include more specific chemical constituents. A complete listing of chemical compounds included in each parameter group is provided in Tables 3-3 and 3-4 for Phases I and II respectively.

The approach used for development of Phases I and II sampling programs is discussed further in Sections 3.4 to 3.7, as well as in the Work Plan (O'Brien & Gere, June 1985) and Site Operations Plan (O'Brien & Gere, November 1986). Additional details regarding modifications made to the sampling plan (such as the collection of additional samples and the exact locations sampled) are addressed in the "Site Investigations" sections for each of the sites (Sections 8-39), and in the figures for the various sampling sites.

The analytical results from Phase I and II are summarized in tabular form in Volume III, Appendix I. Appendix H includes a key to chemical parameter abbreviations and a listing of the units used to express each parameter.

3.4 Rationale for Sample Selection

Historical background information on the Refuge was provided by the Refuge Manager and was summarized for each study site in Attachment 1 to Appendix B of the Work Plan (O'Brien & Gere, June 1985). This background information formed the basis for selection of sites by the Refuge Manager for inclusion in the RI/FS program. In some cases, the background information suggested the types of contaminants which might be present at the site, based on the knowledge of operations which may have contributed to the

contamination. In other cases, the background information was insufficient to identify the potential contaminants of concern, and it was necessary to develop an analytical strategy to screen for a broad range of compounds to determine those of concern.

Field observations and measurements often formed the basis for selecting specific sampling locations and compositing intervals. Relevant field observations included the general topography and drainage patterns, geologic features, areas of unusual soil or sediment discoloration, stressed vegetation, or evidence of scattered, mounded or buried debris. The most significant field observations were described for each sampling site in the Work Plan (O'Brien & Gere, June 1985). These observations were supplemented with figures for each site developed from sketches prepared during the initial site visits (O'Brien & Gere, Work Plan Supplement, December 1985, Attachment S-8, Field Reconnaissance Sketches), to aid in the selection of specific sampling locations.

The two-phase sampling program was described in detail in the Work Plan Supplements for Phases I (December 1985) and II (November 1986). The following topics were addressed:

- Sample types and locations
- Sample equipment and procedures
- Sample handling, custody procedures, and preservation
- Sample documentation
- Sample shipping
- Analytical arrangements (scheduling)
- Analytical procedures
- QA/QC review procedures of data
- Analytical review of data

- Disposal of unused samples

The rationale applied for selection of sample locations (including depth, location, and compositing details) and the selection of analytical parameters for those samples was presented in Attachments S-3 and S-4 of the Work Plan Supplement, December 1985. Final listings of the samples scheduled for Phases I and II sampling and analysis are included in this report as Appendices F and G of Volume II.

Analytical procedures that were used for screening as well as full analysis of HSL organics, metals, dioxins and dibenzofurans, and other parameters are referenced in the QAPP document. All analytical procedures are consistent with U.S. EPA protocols, or methods specified by the U.S. FWS, or methods developed for this program.

3.5 Rationale for Selection of Control Sites

Two control sites, Sites 30 and 31, were established in the Work Plan for soil and ground water analyses. A "lake control" was also incorporated into the sampling schedule for Site 34, Crab Orchard Lake.

Site 30, Munitions Control, (see Section 7 and Appendix B of the Work Plan, June 1985), was established because previous experience of Q'Brien & Gere at Department of Defense munitions handling facilities has indicated slight background levels of explosives residuals near bunker storage facilities even though they may be remote from other handling activities. Site 30 was established to determine if there is a similar dispersed presence of explosives residuals at the Refuge.

Another factor in the selection of Site 30 is that the geology south of Crab Orchard Lake is significantly different from that north of the Lake. The area now occupied by Crab Orchard Lake represents the approximate boundary

of glacial advancement during the Illinoian glacial epoch which represents the furthest glacial advance in the area (Frye, 1965).

The Refuge Control, Site 31 was established in an area remote from any past industrial activities and adjacent to the Refuge Headquarters. According to the Refuge Manager, previous analyses of ground water near this site did not indicate the presence of substances of concern. Sites 22, the Old Refuge Shop, and Site 29, the Fire Station landfill, which are located north of the Refuge control, are expected to drain west and east, respectively, and should not influence Site 31.

The Lake Control as a part of Site 34 (see Section 21 and Appendix B of the Work Plan) is located at the dam adjacent to the spillway within the western end of the lake. Previous analyses of biota and sediments have indicated that contaminant concentrations are very low to undetectable in this region of Crab Orchard Lake (Ruelle, March 1983; Ruelle, February 1983; Ruelle and Adams, April, 1984).

3.6 Phase I Sampling and Analysis

Phase I efforts consisted of geophysical surveys, hydrogeologic investigations, installation of ground water monitoring wells, and a screening of each site to analyze for a broad array of potential contaminants over a wide area. Selected samples were confirmed by a full analysis for the HSL organics.

A specific listing of sampling locations, matrices, analytical parameters and dates of collection is included in Appendix F. The sampling locations are depicted on the site maps in Sections 8 through 39. Table 3-1 lists the parameters analyzed under each analytical set (A-H) for Phase I samples. Table 3-3 is a list of chemical compounds included in each parameter group from Table 3-1. A summary of the samples collected for each site with their

respective analytical sets is presented in Table 3-5. A total of 498 samples including water, soil and sediment matrices were collected. No ground water samples were collected during Phase I. Field sampling for Phase I was completed in November 1985.

3.7 Phase II Sampling and Analysis

A preliminary evaluation of the analytical results from Phase I was performed to select additional samples and chemical parameters for Phase II analyses. The purpose of the Phase II investigation was to fill data gaps identified in Phase I and to define the extent of contamination (both vertically and laterally) at each site identified during Phase I as an area of concern. Table 3-6 provides a summary of the samples collected in Phase II organized by site and analytical sets. Phase II analytical parameters and a listing of compounds are provided in Tables 3-2 and 3-4 respectively.

The sampling and analysis schedule for Phase II samples is contained in Appendix G. This schedule details the sample locations, sampling dates, sample designations and analytical sets associated with each sample. Sampling locations are depicted in the site maps contained in each section. A total of 485 samples included water (surface and ground water), soil, sediment and biota matrices. All ground water samples collected for metals analysis were filtered¹ in the field prior to acidification. Field sampling for Phase II was completed in December 1986.

¹ Small amounts of sediment are often present in properly-developed monitoring wells. These sediments, which contain naturally-occurring minerals, would not be expected to migrate with ground water flow nor be present in a water supply well. It is standard practice, therefore, to use filtered metal analyses from monitoring wells to assess ground water quality.

TABLE 3-5 (page 1 of 3)

SUMMARY OF PHASE I SAMPLING AND ANALYSES
(See Table 3-3 for List of Analysis Sets)

SITE NO.	SAMPLE TYPE	WATER		SOILS		SEDIMENTS	
		NO. OF SAMPLES	ANALYSIS SET	NO. OF SAMPLES	ANALYSIS SET	NO. OF SAMPLES	ANALYSIS SET
3 AREA 11 SOUTH		0	-	3 1	A F	1 1	A D
4 AREA 11 NORTH		0	-	1	D	1 1	A F
5 AREA 11 ACID POND		1	A	1	A	1 1	A F
7 D AREA SOUTHEAST DRAINAGE		1	A	0	-	1	A
7A D AREA NORTH LAWN		0	-	16 1	A F	0	-
8 D AREA SOUTHWEST DRAINAGE		1	A	0	-	1	A
9 D AREA NORTHWEST DRAINAGE		1	A	0	-	1	A
10 WATERWORKS NORTH DRAINAGE		1	A	0	-	1 1	D G
11 P AREA SOUTHEAST DRAINAGE		1	A	0	-	1 1	A F
11A P AREA NORTH		0	-	4	A	4 1	A F
12 AREA 14 IMPOUNDMENT		0	-	1	D	1 1	A G
13 AREA 14 CHANGE HOUSE SITE		0	-	6	A	0	-
14 AREA 14 SOLVENT STORAGE		2	A	0	-	2 1	A F
15 AREA 7 PLATING POND		1	A	0	-	1	A
16 AREA 7 INDUSTRIAL SITE		2	A	7 2 1 1	A D F G	3 1	A F
17 JOB CORPS LANDFILL		2	A	5 2 2	A D G	0	-
18 AREA 13 LOADING PLATFORM		0	-	4 1	A F	0	-
19 AREA 13 BUNKER 1-3		0	-	5	A	0	-

SUMMARY OF PHASE I SAMPLING AND ANALYSES
(See Table 3-3 for List of Analysis Sets)

SITE NO.	SAMPLE TYPE	WATER		SOILS		SEDIMENTS	
		NL OF SAMPLES	ANALYSIS SET	NL OF SAMPLES	ANALYSIS SET	NL OF SAMPLES	ANALYSIS SET
				1	F		
20 B AREA SOUTH		0	-	0	-	1	A
						1	F
21 SOUTHEAST CORNER FIELD		0	-	4	A	0	-
				1	F		
22 OLD REFUGE SHOP		1	A	0	-	1	A
						1	F
24 PEPSI-WEST		1	A	0	-	1	A
						1	F
25 C. O. CREEK AT MARION LF		3	A	0	-	2	A
						1	D
						1	G
26 C. O. CREEK BELOW MARION STP		2	A	0	-	2	A
27 C. O. CREEK BELOW 157 DREDGE		1	A	0	-	1	D
28 WATER TOWER LANDFILL		0	-	11	A	0	-
				1	D		
				1	G		
29 FIRE STATION LANDFILL		0	-	5	A	0	-
				2	D		
				1	G		
30 MUNITIONS CONTROL SITE		0	-	1	D	0	-
				1	G		
31 REFUGE CONTROL SITE		0	-	1	D	0	-
				1	G		
32 AREA 9 LANDFILL		0	-	1	A	15	A
				8	B	3	D
				27	C		
				9	H		
33 AREA 9 BUILDING COMPLEX		0	-	184	B	0	-
				4	D		
34 CRAB ORCHARD LAKE		5	E	0	-	0	-
35 AREA 9 EAST WATERWAY		0	-	0	-	1	A
						1	F
TOTAL NUMBER OF ANALYSES		26		328		61	415

TABLE 3-5 (page 3 of 3)

SUMMARY BY ANALYSIS SETS OF PHASE I
 (See Table 3-3 for List of Analysis Sets)

NO. OF ANALYSES	SCREENING					SUB-TOTAL	FULL ANALYSIS			TOTAL
	A	B	C	D	E		F	G	H	
SURFACE WATER	21	0	0	0	5	26	0	0	0	26
SOILS	72	192	27	15	0	306	6	7	9	328
SEDIMENTS	41	0	0	7	0	48	10	3	0	61
SUB-TOTAL	134	192	27	22	5	380	16	10	9	415
QA/QC - SURFACE WATER	1	0	0	0	0	1	0	0	0	1
QA/QC - SOIL	12	31	4	6	0	53	1	2	2	58
QA/QC - SEDIMENT	7	0	0	1	0	8	2	1	0	11
QA/QC - BLANKS	8	0	0	1	0	9	0	1	1	11
QA/QC - TOTAL	28	31	4	8	0	71	3	4	3	81
TOTAL	162	223	31	30	5	451	19	14	12	496

NOTE: Groundwater and biota samples included in PHASE II

Table 3-6 (page 1 of 4)

PHASE II SAMPLING AND ANALYSES SUMMARY BY SITES
 (See Table 3-2 for List of Analytical Sets)

SITE NOL	SAMPLE TYPE	WATER		WELL		SOILS		SEDIMENTS		BIOTA	
		NOL OF SAMPLES	ANALYSIS SET	NOL OF SAMPLES	ANALYSIS SET	NOL OF SAMPLES	ANALYSIS SET	NOL OF SAMPLES	ANALYSIS SET	NOL OF SAMPLES	ANALYSIS SET
NOTE: * indicates re-sampling/re-analysis of Phase I samples											
3 AREA 11 SOUTH		No Phase II sampling and/or analysis									
4 AREA 11 NORTH		No Phase II sampling and/or analysis									
5 AREA 11 ACID POND		No Phase II sampling and/or analysis									
7 D AREA SOUTHEAST DRAINAGE		0	-	0	-	0	-	1	AJ *	0	-
7A D AREA NORTH LAWN		0	-	0	-	6	AJ *	0	-	0	-
8 D AREA SOUTHWEST DRAINAGE		No Phase II sampling and/or analysis									
9 D AREA NORTHWEST DRAINAGE		0	-	0	-	0	-	1	K *	0	-
10 WATERWORKS NORTH DRAINAGE		1	J	0	-	0	-	5 1	J AJ *	0	-
1 P AREA SOUTHEAST DRAINAGE		1	K *	0	-	0	-	1	AJ *	0	-
11A P AREA NORTH		0	-	0	-	1	AJ *	0	-	0	-
12 AREA 14 IMPOUNDMENT		No Phase II sampling and/or analysis									
13 AREA 14 CHANGE HOUSE SITE		No Phase II sampling and/or analysis									
14 AREA 14 SOLVENT STORAGE		1	L	0	-	0	-	1	L	0	-
15 AREA 7 PLATING POND		0	-	1	M	0	-	1	M	0	-
16 AREA 7 INDUSTRIAL SITE		1	O	0	-	0	-	1	O	0	-
17 JOB CORPS LANDFILL		2	V	5	W	35 12	P Q	6	Q	0	-
18 AREA 13 LOADING PLATFORM		No Phase II sampling and/or analysis									
19 AREA 13 BUNKER 1-3		0	-	0	-	1	AJ *	0	-	0	-
20 D AREA SOUTH		1	K *	0	-	0	-	0	-	0	-
21 SOUTHEAST CORNER FIELD		0	-	0	-	1	AJ *	0	-	0	-
22 OLD REFUGE SHOP		0	-	1	U	1	Z	3 1	R Z	0	-
24 PEPSI-WEST		0	-	0	-	0	-	1	AJ *	0	-

Table 3-6 (page 2 of 4)

PHASE II SAMPLING AND ANALYSES SUMMARY BY SITES
 (See Table 3-2 for List of Analytical Sets)

SITE NO.	SAMPLE TYPE	WATER		WELL		SOILS		SEDIMENTS		BIOTA	
		NO. OF SAMPLES	ANALYSIS SET	NO. OF SAMPLES	ANALYSIS SET	NO. OF SAMPLES	ANALYSIS SET	NO. OF SAMPLES	ANALYSIS SET	NO. OF SAMPLES	ANALYSIS SET
NOTE: * indicates re-sampling/re-analysis of Phase I samples											
25	C.O. CREEK AT MARION LF	0	-	0	-	0	-	1	AA *	0	-
26	C.O. CREEK BELOW MARION STP	No Phase II sampling and/or analysis									
27	C.O. CREEK BELOW 157 DREDGE	No Phase II sampling and/or analysis									
28	WATER TOWER LANDFILL	0	-	4	S	6	AB	0	-	0	-
29	FIRE STATION LANDFILL	0	-	5	S	13 6	AC AJ *	0	-	0	-
30	MUNITIONS CONTROL SITE	0	-	1	X	1	Y	0	-	0	-
31	REFUGE CONTROL SITE	0	-	1	X	1	Y	0	-	0	-
32	AREA 9 LANDFILL	0	-	5	AG	33	AE	37 5	AF AD	0	-
33	AREA 9 BUILDING COMPLEX	0	-	3	X	148 3	B AI	0	-	0	-
34	CRAB ORCHARD LAKE	10 5	AL AK	0	-	0	-	8 2	I AH	30	T
35	AREA 9 EAST WATERWAY	No Phase II sampling and/or analysis									
TOTAL NUMBER OF ANALYSES		22		26		268		76		30	422

Table 3-6 (page 3 of 4)

PHASE II SAMPLING AND ANALYSES SUMMARY BY SETS
(See Table 3-2 for List of Analytical Sets)

NO. OF ANALYSES	ANALYSIS SET															
	D	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
SURFACE WATER	0	0	1	2	1	0	0	1	0	0	0	0	0	0	2	0
GROUNDWATER	0	0	0	0	0	1	0	0	0	0	0	9	0	1	0	5
SOILS	148	0	0	0	0	0	0	0	35	12	0	0	0	0	0	0
SEDIMENTS	0	8	5	1	1	0	1	1	0	6	3	0	0	0	0	0
FISH	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0
SUB-TOTAL	148	8	6	3	2	1	1	2	35	18	3	9	30	1	2	5
QA/QC - SURFACE WATER	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0
QA/QC - GROUNDWATER	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	3
QA/QC - SOIL	23	0	0	0	0	0	0	0	5	9	0	0	0	0	0	0
QA/QC - SEDIMENT	0	5	1	0	0	0	0	0	0	1	1	0	0	0	0	0
QA/QC - FISH	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0
QA/QC - BLANKS	9	0	1	0	0	0	0	0	1	7	0	0	0	0	1	0
QA/QC - TOTAL	32	5	2	0	1	0	0	0	6	17	1	2	10	0	4	3
TOTAL	180	13	8	3	3	1	1	2	41	35	4	11	40	1	6	8

Table 3-6 (page 4 of 4)

PHASE II SAMPLING AND ANALYSES SUMMARY BY SETS
(See Table 3-2 for List of Analytical Sets)

NL. OF ANALYSES	ANALYSIS SET (Cont'd)															TOTAL
	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	
SURFACE WATER	0	0	0	0	0	0	0	0	0	0	0	0	0	5	10	22
GROUNDWATER	5	0	0	0	0	0	0	0	0	5	0	0	0	0	0	26
SOILS	0	2	1	0	6	13	0	33	0	0	0	3	15	0	0	268
SEDIMENTS	0	0	1	1	0	0	5	0	37	0	2	0	4	0	0	76
FISH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
SUB-TOTAL	5	2	2	1	6	13	5	33	37	5	2	3	19	5	10	422
QA/QC - SURFACE WATER	0	0	0	0	0	0	0	0	0	0	0	0	0	8	7	19
QA/QC - GROUNDWATER	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
QA/QC - SOIL	0	1	1	0	1	4	0	3	0	0	0	1	2	0	0	50
QA/QC - SEDIMENT	0	0	0	0	0	0	5	0	10	0	1	0	1	0	0	25
QA/QC - FISH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
QA/QC - BLANKS	1	1	0	0	1	1	1	0	1	3	0	0	0	2	3	33
QA/QC - TOTAL	2	2	1	0	2	5	6	3	11	4	1	1	3	10	10	144
TOTAL	7	4	3	1	8	18	11	36	48	9	3	4	22	15	20	566

SECTION 4 - SITE INVESTIGATION METHODS

4.1 Introduction

The site investigations conducted at the Crab Orchard Refuge are discussed in general in this section. Details on specific sites are presented in Sections 8 through 39.

4.2 Hydrogeologic Investigations

The hydrogeologic investigations conducted during Phase I and Phase II were directed at obtaining sufficient data to permit an evaluation of the hydrogeologic conditions at the Refuge. Hydrogeologic investigations conducted at the different sites consisted of: a preliminary review of existing hydrogeologic data; the performance of geophysical surveys, soil borings, soil sampling, ground water monitoring, well installation, permeability testing, an engineering survey of the installed wells, ground water elevation monitoring, and ground water sampling. The following subsections describe field activities which have been performed.

4.2.1 Geophysical Surveys

Two types of terrain geophysical surveys (Electromagnetic Induction and Magnetometer) were conducted during Phase I at selected sites. These surveys were performed to evaluate the nature of the conductive properties of the fill deposits in comparison to naturally-occurring soils. Surveys of this type are often used to detect buried conductive and resistive objects such as metallic debris, drums, and free-phase liquids originating from waste disposal practices. Results of these surveys are included in the figures accompanying Sections 8 through 39, and the raw

data are included as Appendix A. The following sites were surveyed by using an EG&G Geometric Proton Magnetometer (Model G816/826) and a Geonics EM 31-D Terrain Conductivity Meter:

Site

- 29 Fire Station
- 13 Area 14 Change House
- 21 Southeast Corner Field
- 17 Job Corps Landfill
- 28 Water Tower Landfill
- 7A D Area North Lawn

During the magnetometer survey at each site, a base station was set up and periodically checked during the survey to monitor diurnal variations in the earth's magnetic field. Measurements of total magnetic field intensity were then obtained at 25 foot intervals along survey lines established at each site and recorded when a consistent reading within 10 gammas was obtained. Readings from the electromagnetic survey were also collected every 25 feet along surveyed lines at each site and recorded in micromhos/meter. Since no variations of the earth's magnetic field were detected, no corrections were necessary.

Data which were averaged at each point in the surveys were then plotted on site maps and entered into a computer topographic contouring program developed by the National Center for Atmospheric Research (NCAR). Resultant plots which indicate anomalous magnetic and electromagnetic features are shown in the figures developed for each site. In most surveys, surficial interferences such as power lines, metal debris, etc. were noted in the field and filtered out of the survey data; therefore, anomalies as indicated on the plots may be due to buried

ferrous objects or other conductive debris or liquids. The amplitude of each anomaly is indicative of the size or extent of a buried feature relative to its depth. The same anomaly could be produced from a small object at shallow depth or a large object located in a deeper position. Therefore, depth calculations to anomalous features are subjective and were not included as part of the investigations.

4.2.2 Soil Borings

Soil borings were completed at selected sites during Phases I and II. The purpose of the soil borings in both phases was to evaluate the nature of the soil veneer underlying each site including an evaluation of soil type, thickness, horizontal continuity, and to establish the depth to the encountered ground water for subsequent monitoring well installations. Soil borings were also used to collect subsurface samples to determine the vertical extent of contamination.

Boring logs including a description of soils encountered, standard penetration resistance, and other pertinent data are contained in Appendix B for Phase I and Appendix C for Phase II.

Test borings were advanced by use of 3-1/4 inch inside diameter hollow stem drilling augers with soil core samples collected every five feet or as indicated by the supervising hydrogeologist. Drill cuttings developed during each respective test boring were left in place adjacent to the test boring. Soil cores were collected in accordance with American Society for Testing and Materials (ASTM) Method D-1586-67 sampling protocols. A standard 2-inch outside diameter, 30 inch length split spoon sampler was used to obtain the samples. Soil borings were generally advanced to auger or split spoon penetration refusal which indicated the

top of bedrock in the area. Occasionally, soil borings were advanced to a pre-determined depth for the purpose of monitoring well placement within a specified aquifer zone or for the purpose of constructing nested well pairs.

Selected soil samples from the Phase II test borings were submitted for standard ASTM Method D-422-63 sieve and hydrometer analyses. The purpose of these analyses was to provide information on soil compositions at varying depths to be used in evaluations of the site hydrogeology and remediation alternatives. Soil types representative of those encountered in each boring conducted in Phase II were tested to provide an analysis of each soil type encountered. The results are contained in Appendix D.

4.2.3 Ground Water Monitoring Well Installations

Following the completion of soil borings in Phases I and II, well screens and risers were installed at depths designed to provide the necessary information regarding the hydrologic characteristics of subsurface aquifers. At some sites, different aquifer zones were monitored by the installation of well nests to facilitate an evaluation of the interaction between the two aquifer zones.

For wells installed in Phase I, standard monitoring well installation material included 10 ft. sections of 2-inch I.D. No. 10 slot, Schedule 40 NSF approved PVC screen and compatible riser. A well screen and riser were installed at the bottom of the borehole. A No. 4 washed silica sand pack was placed around the well screen as the auger casing was pulled back to a depth of about 2 ft. above the well screen. A 1-to 2-foot thick bentonite pellet seal was then installed above the sand pack and the remaining annulus surrounding the riser grouted with Portland

cement/bentonite grout. At the surface, a locking steel protective casing was installed and cemented in place to secure the well riser and prevent unauthorized entry. Well designations, specifications and depths are given in Table 4-1.

Monitoring wells installed during Phase II utilized 5 ft. sections of Type 316, 2-inch diameter stainless steel well screens five feet in length connected to an NSF approved 2-inch diameter PVC riser casing. The screen and riser assembly was lowered into the augers to a specified depth and a washed silica sand pack (No. 4 Q-Rock) was installed around the screen. A bentonite pellet seal 1 to 2 foot-thick was then installed on top of the sand and the remaining annulus around the well riser was grouted with Portland cement/bentonite. A locking protective steel casing was then inserted over the well riser and cemented to ensure an adequate surface seal.

Following well installation, all wells were developed using a portable air compressor and tubing assembly. The purpose of the well development was to remove most of the fine grained sediment which could have entered the well during installation and to enhance the hydraulic connection between the aquifer and well screen. Well development involved injecting filtered, compressed air through cleaned tubing into the screened portion of each well to clear the slot openings. Discharged water was allowed to flow at ground surface and was monitored until a relatively sediment-free appearance was noted.

4.2.4 Well and Soil Boring Location Survey

A well elevation and location survey was conducted in June 1987. The well locations are referenced by coordinates relative to an arbitrary origin. Coordinates of the well locations provide an accuracy of ± 100 ft.

between individual sites and an accuracy of ± 1 ft. between wells within individual sites. Well elevations are referenced by benchmark elevations given for two highway intersections of Ogden Road and Old Route 13 with Route 148. Monitoring well elevations were surveyed to an accuracy of ± 0.01 ft. for the top of the PVC casings and protective steel casings, and ± 0.1 ft. for ground level elevations. Data are presented in Table 4-2.

4.2.5 Ground Water Elevation Monitoring

Ground water levels within monitoring wells installed during Phases I and II have been measured on several occasions and are included on the boring logs presented in Appendices B and C. Table 4-3 includes depths to ground water below ground surface and ground water elevations for all wells as measured in December 1985, January 1987, and June 1987. All depths to ground water were measured relative to ground level and the top of the PVC riser located within the protective steel casing.

4.2.6 Hydraulic Conductivity Testing

In-situ hydraulic conductivity tests were conducted on all monitoring wells. The purpose of the tests was to provide an indication of the capacity of the screened portions of subsurface aquifers to transmit ground water. Hydraulic conductivity values were calculated in both feet per second and centimeters per second and are presented in Table 4-4. Supporting calculations are contained in Appendix E.

The in-situ permeability tests were conducted for most wells in January 1987 and for wells 15-4, 30-2, and 31-2 in June 1987. Prior to initiating the tests, static water elevations were measured. The tests performed in January 1987 were accomplished by rapidly inserting solid

TABLE 4-1

WELL SPECIFICATIONS AND DEPTHS

<u>Site</u>	<u>Boring #</u>	<u>Total Depth</u>	<u>Screened Interval</u>	<u>Aquifer Screened</u>	<u>Phase Installed</u>
15, Acid Pond	15-4	15'	5-15'	Clayey Silt	I
17, Job Corps Landfill	17-8	15'	10-15'	Silty Clay	II
	17-9	12'	7-12'	Silty Clay	II
	17-10	12'	7-12'	Silty Clay	II
	17-11	12'	7-12'	Silty Clay	II
	17-65	30'	25-30'	Silty Clay	II
22, Old Refuge Shop	22-8	10'	5-10'	Silty Clay	II
28, Water Tower Landfill	28-7	25'	15-25'	Clayey Silt	I
	28-8	20'	10-20'	Clayey Silt	I
	28-15	39'	34-39'	Sand	II
	28-16	20.5'	15.5-20.5'	Clayey Silt	II
29, Fire Station Landfill	29-8	30'	20-30'	Sandstone	I
	29-9	25'	15-25'	Clayey Silt	I
	29-10	23'	13-23'	Sandstone	I
	29-11	16'	6-16'	Clayey Silt and Sandstone	I
30, Munition Control Site	30-2	20'	10-20'	Clayey Silt	I
31, Refuge Control Site	31-2	30'	20-30'	Clayey Silt	I
32, Area 9 Landfill	32-63	15'	10-15'	Silty Clay	II
	32-109	15'	10-15'	Silty Clay	II
	32-110	82.5'	77.5-82.5'	Sand	II
33, Area 9 Building Complex	33-340	15'	10-15'	Silty Clay	II
	33-341	14'	9-14'	Silty Clay	II
	33-342	20'	15-20'	Silty Clay	II

TABLE 4-2
WELL SURVEY DATA

<u>Well No.</u>	<u>Coordinate</u>	<u>Coordinate</u>	<u>Elevation</u>	<u>Casing El.</u>	<u>Pipe El.</u>
15-4	18485	33832	433.4	436.81	436.45
17-8	35423	13814	423.8	427.01	426.83
17-9	35215	12956	425.4	428.88	428.23
17-10	35204	12813	425.4	428.53	428.37
17-11	35298	12682	425.4	428.46	428.30
17-65	35221	12863	425.4	428.90	428.76
22-8	34228	24011	440.2	443.50	443.34
28-7	17898	31475	433.2	436.77	436.68
28-8	17736	31475	435.2	438.47	438.39
28-15	17909	31486	433.5	436.70	436.68
28-16	17662	31128	453.0	455.80	455.64
29-8	33035	25923	441.6	444.94	444.89
29-9	32731	25919	440.7	444.06	443.94
29-10	32455	25695	438.2	440.57	440.33
29-11	33452	25256	441.6	445.04	444.76
30-2	14667	12206	436.1	439.50	439.34
31-2	30630	23863	425.2	428.15	428.06
32-61	22703	26492	412.8	415.41	414.94
32-62	22872	26681	408.5	410.82	410.49
32-63	21938	26703	415.9	419.10	418.93
32-109	22714	26871	407.8	411.15	411.01
32-110	22723	26865	407.6	410.91	410.89
33-340	21905	26015	424.9	428.29	428.17
33-341	19887	26974	425.9	429.44	429.31
33-342	19251	26772	429.6	432.94	432.81

TABLE 4-3

WELL DATA AND GROUND WATER ELEVATION TABLE

Well	Elev. Top PVC	Elev. Top Casing	Elev. G.L.	Date	Depth *	Elev.	Date	Depth *	Elev.	Date	Depth **	Elev.
15-4	436.45	436.81	433.4	15 Dec 86	1.8'	431.6	--	--	--	18 June 87	8.33'	428.12
17-8	426.83	427.01	423.8	12 Dec 86	3.2'	420.6	20 Jan 87	2.0'	421.8	18 June 87	8.23'	418.60
17-9	428.23	428.88	425.4	13 Dec 86	2.6'	422.8	20 Jan 87	3.0'	422.4	18 June 87	6.98'	421.25
17-10	428.37	428.53	425.4	13 Dec 86	2.6'	422.8	20 Jan 87	1.8'	423.6	18 June 87	8.21'	420.16
17-11	428.30	428.46	425.4	13 Dec 86	2.7'	422.7	20 Jan 87	1.8'	423.6	18 June 87	7.98'	420.32
17-65	428.76	428.90	425.4	13 Dec 86	15.4'	410.0	20 Jan 87	2.3'	423.1	18 June 87	7.78'	420.98
22-8	443.34	443.50	440.2	---	--	--	19 Jan 87	0.8'	439.4	18 June 87	4.25'	439.09
28-7	436.68	436.77	433.2	15 Dec 86	2.1'	431.1	20 Jan 87	1.5'	431.7	18 June 87	9.38'	427.30
28-8	438.39	438.47	435.2	15 Dec 86	1.9'	433.3	20 Jan 87	1.4'	433.8	18 June 87	8.71'	429.68
28-15	436.68	436.70	433.5	15 Dec 86	3.1'	430.4	20 Jan 87	2.0'	431.5	18 June 87	6.31'	430.37
28-16	455.64	455.80	453.0	15 Dec 86	15.7'	437.3	21 Jan 87	15.0'	438.0	18 June 87	20.02'	435.62
29-8	444.89	444.94	441.6	14 Dec 86	5.5'	436.1	19 Jan 87	4.8'	436.8	18 June 87	10.77'	434.12
29-9	443.94	444.06	440.7	14 Dec 86	3.3'	437.4	20 Jan 87	2.5'	438.2	18 June 87	10.69'	433.25
29-10	440.33	440.57	438.2	14 Dec 86	0.8'	437.4	20 Jan 87	0.4'	437.8	18 June 87	4.46'	435.87
29-11	444.76	445.04	441.6	14 Dec 86	0.8'	440.8	20 Jan 87	0.8'	440.8	18 June 87	6.27'	438.49
30-2	439.34	439.50	436.1	13 Dec 86	7.0'	429.1	--	--	--	18 June 87	15.36'	423.98
31-2	428.06	428.15	425.2	12 Dec 86	12.7'	412.5	--	--	--	18 June 87	17.75'	410.31
32-61	414.94	415.41	412.8	17 Dec 86	0.8'	412.0	21 Jan 87	1.0'	411.8	19 June 87	7.98'	406.96
32-62	410.49	410.82	408.5	17 Dec 86	0.1'	408.4	21 Jan 87	2.0'	408.5	19 June 87	5.11'	405.38
32-63	418.93	419.10	415.9	17 Dec 86	2.9'	413.0	21 Jan 87	2.0'	413.9	19 June 87	9.56'	409.37
32-109	411.01	411.15	407.8	17 Dec 86	2.8'	405.0	21 Jan 87	1.0'	406.8	19 June 87	12.92'	398.09
32-110	410.89	410.91	407.6	---	ARTESIAN	---	---	ARTESIAN	---	---	ARTESIAN	---
33-340	428.17	428.29	424.9	17 Dec 86	6.9'	418.0	21 Jan 87	8.3'	416.6	19 June 87	14.08'	414.09
33-341	429.31	429.44	425.9	15 Dec 86	1.2'	424.7	21 Jan 87	0.8'	425.1	19 June 87	6.23'	423.08
33-342	432.81	432.94	429.6	15 Dec 86	6.6'	423.0	21 Jan 87	6.4'	423.2	19 June 87	12.42'	420.39

Note: G.L. - Ground Level)

* - Depth Measured from Ground Level)

** - Depth Measured from Top PVC

pieces of teflon rod into the water column in the well, thereby displacing the water column upward and creating a potential for flow from the well to the surrounding aquifer. The rate of decline of the water level within the well was then monitored as it equilibrated with the aquifer. When the water level approached the original static water level, the rod was then removed, which lowered the water level in the well to a depth lower than the water table in the surrounding aquifer. This created a potential for flow into the well, which also was monitored until the water level returned close to the static level.

Ground water levels were monitored during these permeability tests using an Enviro-Labs Data Logging System, a conventional analog signal generating pressure transducer which directly measures feet of hydraulic head to one-hundredth (.01) of one foot. The tests performed in June 1987 were accomplished by rapidly withdrawing water by bailing methods from the wells, which lowered the water level in the wells to depths lower than the water table in the surrounding aquifers. This created a potential for flow into the wells, which was monitored until water levels returned close to the static levels with an electronic water level probe. Hydraulic conductivities have been calculated for all wells using Hvorslev's method, and the data are presented on Table 4-4. In general, the data indicate the soils to exhibit hydraulic conductivities typical of the silts and sands encountered. Values of hydraulic conductivities obtained from wells installed within the first encountered aquifer at the Old Refuge Shop, Job Corps Water Tower, Fire Station, and Area 9 Landfill sites generally ranged from 10^{-3} to 10^{-5} cm/sec. One shallow well at the Water Tower landfill exhibited a lower hydraulic conductivity of 7×10^{-6} cm/sec. Deeper wells installed at the above mentioned sites

exhibited higher hydraulic conductivities of 10^{-3} to 10^{-4} cm/sec consistent with sandier soils encountered at those depths.

4.2.7 Regional Hydrogeologic Conditions

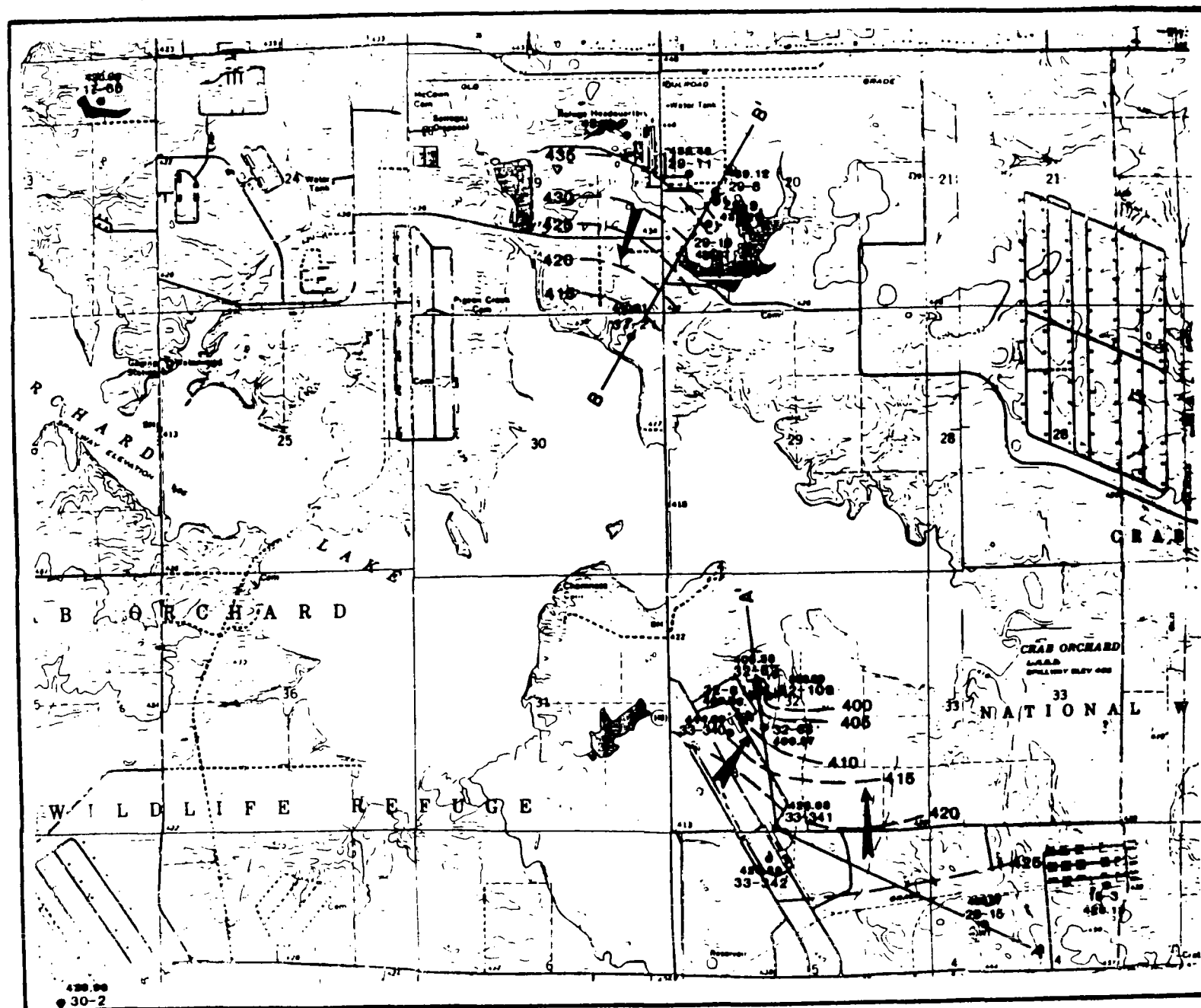
Data obtained from soil borings, well installations, hydraulic conductivity testing, and land surveying were used to evaluate the regional ground water flow conditions in the area of study. The individual sites investigated were located to the north and south of Crab Orchard Lake. As such, data gathered from each site were incorporated into a regional site map displaying ground water flow conditions during June 18-19, 1987. Hydrogeologic cross sections were also constructed on the north and south sides of the lake through the Fire Station Landfill, Refuge Control Site, and the Water Tower Landfill, Area 9 Landfill and Building Complex, respectively. The regional ground water contour and flow direction map is shown as Figure 4-1 including the location of the cross sections. The hydrogeological cross sections are shown as Figure 4-2.

Occurrence of Ground Water

Shallow ground water occurring beneath the sites investigated was generally found at a depth of 1 to 17 feet below ground surface within a silty clay-clayey silt soil unit. Monitoring wells generally screened this upper water table. Ground water elevations collected during the winter of 1987 and summer 1987 (wet and dry seasons respectively) indicated a water table fluctuation of 3 to 10 feet with water levels dropping during the summer months (see Table 4-3).

A lower ground water aquifer was encountered in the lower portions of the soil sequence on top of bedrock where sandier soils were

FIGURE 4-1



REGIONAL GROUNDWATER FLOW MAP



LEGEND

- LINE OF HYDROLOGIC CROSS SECTION
- WELL LOCATION
GROUNDWATER ELEV. 6/18/71
- GROUNDWATER CONTOUR
- FLOW DIRECTION

SCALE IN FEET



HYDROGEOLOGIC CROSS SECTIONS

A-A', B-B'

(GROUNDWATER ELEVATIONS 6/18/87)

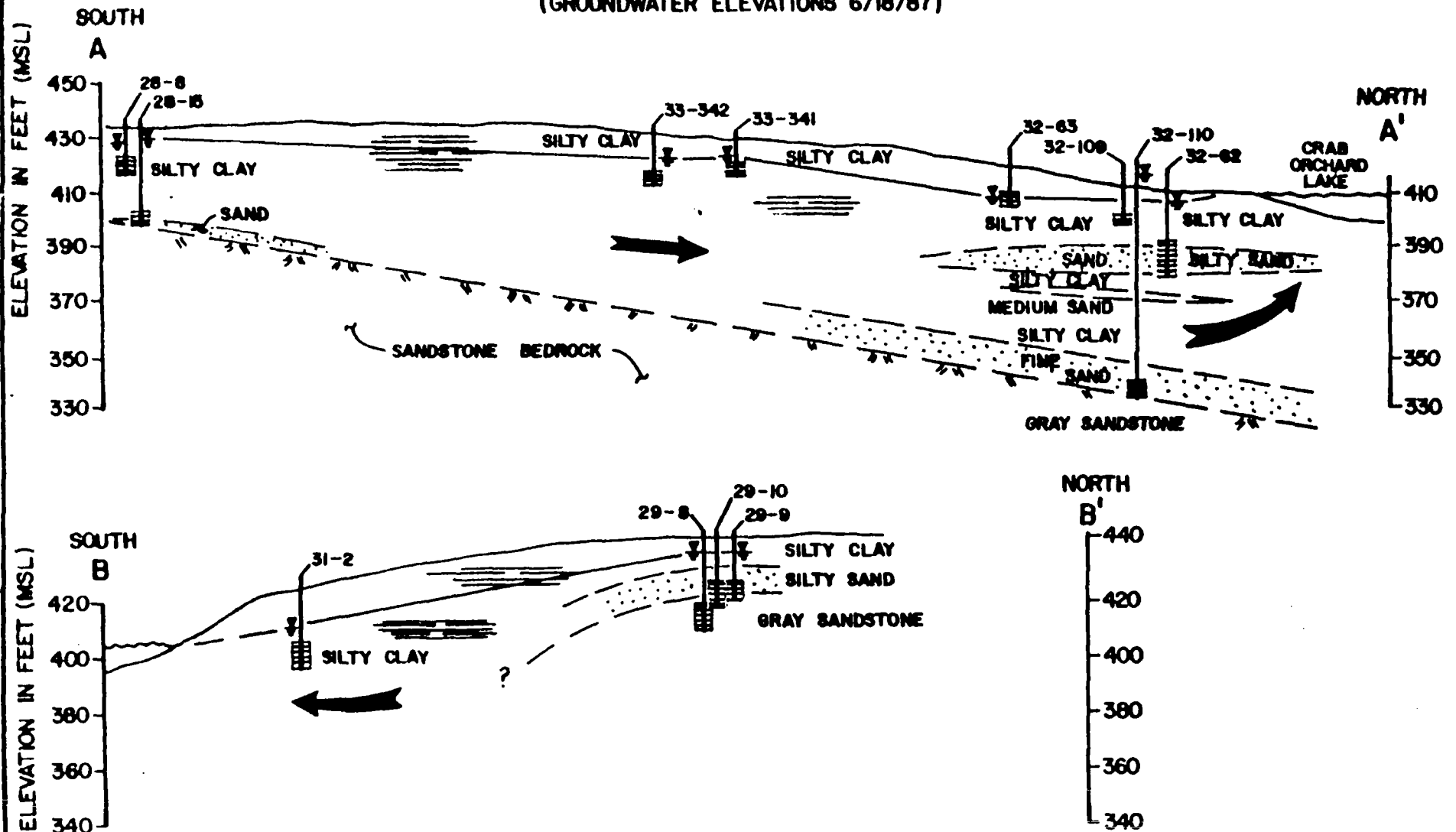


FIGURE 4-2

encountered. Deeper monitoring wells at selected sites 17, 28 and 32 which screened this water bearing unit (bedrock-soil interface) indicated the unit to be confined at Sites 28 and 32 and unconfined at Site 17. An artesian condition was noted at Site 32 with ground water from the sand unit at depths of 77-81 feet flowing at ground surface. This phenomenon is attributed to a hydraulic connection of the said unit to a distant source area higher than that occurring at the well head.

Ground Water Flow Conditions

As can be seen from Figure 4-1 which presents regional horizontal ground water flow directions and contours near the lake (June 1987), shallow ground water flows toward the lake with contours closely resembling topographic contours. This is typical of unconfined ground water flow conditions. Minor undulations in the ground water flow contours are most likely due to the existence of surface water tributaries which locally affect shallow ground water flow patterns.

The average velocity of shallow ground water was calculated for areas north and south of the lake during June 1987. The formula utilized for these calculations is adapted from Darcy's flow equation through porous media (Darcy, 1856) and is given as:

$$V_s = \frac{Ki}{n}$$

where:

V_s = Velocity of ground water (ft/day)

K = Hydraulic conductivity (ft/day)

i = Hydraulic gradient (ft/ft)

n = Porosity (dim.)

Average velocity of shallow ground water north of Crab Orchard Lake was about 0.13 ft/day based on an average hydraulic conductivity of 5 ft/day and hydraulic gradient of 0.009 ft/ft. Porosity was assumed to be 0.35 (Davis and Dewiest, 1966: Table 11-5, Clayey Soils). Average velocity south of the lake was calculated to be lower at 0.007 ft/day based on an average hydraulic conductivity of 0.435 ft/day, a gradient of 0.006 ft/ft and a porosity of 0.35.

Ground water occurring within the lower sandy unit on top of bedrock could not be contoured on a regional basis. It is probable, however, that ground water in this unit which was identified to occur north and south of the lake likewise discharges to Crab Orchard Lake. The specific ground water flow conditions at particular sites investigated will be discussed more fully in each respective section.

Three sets of ground water elevations have been collected from all site wells to date; December 18, 1986, January 20, 1987 and June 18, 1987. Readings taken during these periods represent wet and dry seasons respectively. A comparison of ground water flow gradients and directions for Area 9, Sites 32 and 33, was performed for both periods and is shown on Figure 36-4. Since flow directions and gradients were similar at this site during both periods, flow directions displayed on subsequent figures and associated velocity calculations were generated for the most recent data set only (June 1987).

4.3 Soil/Sediment/Water Investigation

Grab and composite samples collected included surface and core soils, sediments from streams, ponds, and Crab Orchard Lake, and waters from ground water wells, surface streams, raw and finished water supplies, and from Crab Orchard Lake.

Areal composites of surface soil/sediment samples were collected by combining equal volumes of grab samples from predetermined locations. The grab surface samples were obtained using standard sampling tools (shovels, scoops, etc.) to collect the top 0-1 foot depth of sediment (from streams) or soil. Sediments from ponds and Crab Orchard Lake were collected using a dredge to capture approximately 0-6 inches of bottom surface sediment from each location. The discrete grab soil/sediments were placed in a clean disposable aluminum pan and homogenized using a large, stainless steel spoon. The composited and/or homogenized grabs were then packed in pre-labeled sample containers and shipped to the respective laboratories for analyses. All sampling tools were decontaminated between samples by rinsing with soap and water followed by rinsing with acetone.

All grab and composite waters were collected in prewashed, pre-labeled, sampling containers, and were preserved and filtered if required prior to shipping to the corresponding laboratories. Grab surface waters were collected directly into the sample containers. Composite water samples were mixed in equal proportions directly in the quart or gallon containers. Ground waters were collected using a stainless steel bailer and filtered in the field using a glass filtration apparatus and a hand vacuum pump. The filtered samples were also preserved prior to shipment. Water samples from Crab Orchard Lake were obtained by compositing discrete samples collected from the surface, mid-depth, and approximately one foot from the bottom. The lake samples were taken using a stainless steel Kemmerer sampler. For each location, equal aliquots from each depth were composited and preserved.

The samples collected as part of Phase I consisted mostly of surface grabs and composites for screening purposes. A total of 498 samples were collected as summarized in Table 3-5. These samples were represented by 26 waters,

328 soils, 61 sediments and 83 Quality Assurance/Quality Control (QA/QC) samples. QA/QC samples included 1 water, 58 soils, 11 sediments, and 13 blanks (water/soil/sediment). Most of the water samples collected in Phase I were not filtered.

Phase II soil/sediment/waters involved selected sites identified from the results of Phase I. As shown in Table 3-6, a total of 512 samples were collected in Phase II, including 22 surface waters, 26 ground waters, 268 soils, 76 sediments, 30 biota samples, and 90 QA/QC samples. The QA/QC samples included 6 surface water, 5 groundwater, 41 soils, 14 sediments, 10 fish and 14 blanks. Most of the water samples collected in Phase II were filtered.

4.4 Fish and Wildlife Investigation

Fish samples were collected during the Phase I investigation of Site 34 and were analyzed during Phase II. The revised Quality Assurance and Quality Control procedures for fish analyses were approved by U.S. EPA in March 1987, and are contained in Addendum 3, Revision 2 of the QAPP. The fish composite samples were analyzed for pesticides/PCBs, mercury, cadmium, and lead.

The Work Plan and Work Plan Supplements contained provisions for the collection and analysis of other biota samples, including shrews, cray fish and turtles. These samples were not collected due to difficulties in locating these species at the Refuge.

Fish samples were collected using gill nets or an electroshocker. Carp and largemouth bass were collected when possible. If these species were not available, other species such as bullhead or catfish were substituted. Single species composite samples consisting of the edible portion of two to five fish each were collected from Crab Orchard Lake. The number of composite

samples and the fish species composited are identified in Table 3-6, Table 38-1 (Section 38), and Appendix G.

4.5 Air Investigations

Air investigations consisted of a screening of each site during Phase I using an HNU photolionization detector. Measurements obtained with the HNU meter indicated that organic constituents were not present at levels above Refuge background. Air monitoring was not performed during Phase II since the Phase I results did not indicate the presence of air contamination.

SECTION 5 - DATA BASE DEVELOPMENT

5.1 Laboratories Utilized

The following laboratories were utilized for analysis of samples collected from the Crab Orchard Refuge:

1. O'Brien & Gere Laboratories, Inc., Syracuse, NY (OBC)
2. Environmental Testing & Certification, Edison, NJ (ETC)
3. Rocky Mountain Analytical, Denver, CO (RMA)
4. Roy F. Weston, Inc., West Chester, PA (Weston)
5. Hazleton Laboratories America, Inc., Madison, WI (HLA)

For Phase I analyses, explosives were analyzed by Roy F. Weston, Inc.; ICP metals, selected priority pollutants, dioxins and dibenzofurans were analyzed by ETC; and all other parameters were analyzed by OBC Laboratories. The laboratories responsible for the Phase II analyses are identified on Table 5-1.

5.2 Field Data

Hydrogeological data obtained in the field are discussed in Section 4 and are presented in Appendices A-E of Volume II. These include boring logs, field permeability measurements and ground water elevations.

5.3 Analytical Results

Analytical parameters for Phases I and II are listed in Appendix H, along with abbreviations and units of expression for each parameter. The analytical results for both phases are presented by site in Appendix I. Raw data reports from each laboratory are included as Appendices K to P of this report.

TABLE 5-1

ANALYTICAL RESPONSIBILITIES - PHASE II

PARAMETERS	OBG	ETC	RMA	RFW	HLA
-----	---	---	---	---	---
1. CLP HSL Full Analysis		W/S			
2. CLP HSL Volatiles		W/S			
3. CLP HSL Base/Neut/Acids		W/S			
4. Nitrosamines (CLP-soil)		W/S			
5. Nitrosamines (low level-water)		W/S			
6. CLP HSL Pesticide/PCB		W/S			B
7. PCBs (general, soil)	S				
8. PCBs (low level, water)	W				
9. PCBs (semi-low, sediment)	S				
10. Metals - CLP HSL			W/S		
11. Metals - NIPDWR (water)			W		
12. Special - Mercury			W/S		
- Cadmium	S		W/S		
- Chromium			W/S		
- Lead	S		W/S		
- Arsenic			W/S		
- Copper			W/S		
- Magnesium	S		W		
13. EP Toxicity - Cr	S				
- Cd, Cr, Pb	S				
14. Cyanide	W/S				
15. Indicators - pH	W/S				
- NH3, NO3, F	W/S				
16. Explosives by HPLC				W/S	
17. Lipids (fish) *					B
18. PCDD/PCDF (sediment)		S			
19. Total Phosphorus	W/S				
20. Grain Size	S				
21. Percent Solids (soil/sed)	W/S	W/S	W/S	W/S	

NOTES: 1. OBG - O'Brien & Gere Laboratories, Syracuse, NY
 ETC - Environmental Testing & Certification, Edison, NJ
 RMA - Rocky Mountain Analytical Labs, Denver, CO
 RFQ - Roy F. Weston Inc., West Chester, PA
 HLA - Hazleton Laboratories America Inc., Madison, WI

2. W/S/B/ denote: W - surface/groundwater
 S - soil/sediment
 B - biota (fish)

Each sample is identified by four ID numbers, as well as with headings which specify:

- the Phase in which it was collected
- the sample number and laboratory number
- matrix
- collection date

The identification key is detailed on the first page of Appendix I. Unless otherwise indicated by a 'W' qualifier in the data listing, all soil and sediment concentrations are reported and described in this report on a dry weight basis.

5.4 Data Validation

5.4.1 Data Validation Procedure

A comprehensive Quality Assurance Project Plan (QAPP) was developed and subsequently revised for Phase II to incorporate the necessary procedures to generate valid data. The Phase II QAPP was reviewed and approved in November 1986 by the corresponding officers of EPA Region V and Fish and Wildlife Service. The validity of the Phase II analytical data was ensured by meeting the specific criteria as listed in the Phase II QAPP. The QA/QC manager, together with individual laboratory group leaders, reviewed the data to verify compliance. The validation process by group leaders included the review of matrix spike (MS) recoveries, surrogate recoveries, comparability of matrix spike duplicate (MSD) analysis, and method blank integrity. Additionally, the group leaders checked for the adherence to accuracy and procedural criteria, unusually high or low parameter values and possible transmittal errors.

The overall objective was to review the raw data outputs, intermediate determinations, and initial calibrations as compared to those categories listed in the Phase II QAPP to determine the acceptability of the individual data points. Based on this review, qualifiers were assigned to each result, where appropriate, to indicate the acceptability of the data. The laboratories involved in this program were required to employ the procedures as listed in Table 10 of the Phase II QAPP, November 1986. Each laboratory analyzed a group of samples for individual analyses. Therefore, data validation was performed on each batch of samples by parameter or scan, and worksheets were developed for each. Copies of these worksheets are included in Appendix J.

The validation process commenced by verifying that samples were extracted and analyzed within the holding times. The reviewer examined the chain of custody sheets, injection logs and QC reports to verify the frequency of initial and continuing calibration data, that the proper volumes of standard solutions were used, and that blanks were incorporated with each batch. The blanks were evaluated to verify that contamination problems were not present. The reviewers then verified the frequency of matrix spike and matrix spike duplicate (MS/MSD) analyses and that the appropriate quantity of standards were used as listed in the Phase II QAPP. Next, the actual sample results were reviewed and detection limits were calculated. All comments or questions were noted on the individual worksheet so that discussions with the individual operators for the specific laboratories could address the possible excursions. The QA/QC manager then assigned qualifiers to each set of samples or parameters depending on the analysis performed.

The data qualifiers are based specifically on the requirements of the Phase II QAPP, however, several data points may be utilized even though the specific criteria may not have been met. Data outside of QA/QC requirements may have been accepted but used solely for Phase I screening purposes. These screening data assisted in the selection of Phase II sampling locations for verification testing.

The reviewers compared what was actually performed by the laboratories to the requirements of the QAPP and the overall program objectives. The intent was to review all the deliverables for completeness and any data anomalies for consistency with the methods cited in the QAPP. The specific qualifiers developed for the data base are included in the key to Appendix I.

The detection limits used in the analysis of samples in this RI/FS were in accordance with the procedures specified in the QAPP. In some cases, the limits used were limited by the analytical instruments, the cost of analysis, the sample volumes used, or the matrices analyzed. The detection limits as referred to throughout the discussions of analytical results are actually the "Contract Required Quantitation Limits", which were approved by the regulatory agencies and the contractors to provide adequate representation of the individual samples.

5.4.2 Phase I Data Assessment

As discussed in Section 3, the principal purpose of the Phase I sampling and analysis program was to screen broad areas to determine if there were specific locations or specific contaminants which required further investigation. Of the 498 samples analyzed during Phase I, 450 (or 92 percent) of these were soils or sediments. Since regulatory

standards or criteria are unavailable for soil/sediment samples, the evaluation of these data consists of relative comparisons. These comparisons were made either to samples from control sites or within each individual site.

An assessment of the Phase I data was conducted by the U.S. EPA, Region V, Contract Laboratory Management Section (CPMS) and the Quality Assurance Office (QAO). A summary of this assessment is contained in a February 18, 1987 letter from the EPA's Remedial Site Project Manager (see Exhibit B). In general, EPA concluded that most of the Phase I positive detections could be relied upon as estimated values for screening purposes. Several exceptions were noted by EPA and these were generally addressed during the Phase II analysis program. For example, mercury data were repeated for several sites during Phase II because of high contaminant concentrations detected in the blanks and poor calibrations in the Phase I data. Phase I cyanide data were also suspect due to QA/QC deficiencies and the analyses were repeated for some sites during Phase II.

Some of the compounds in the Phase I CLP Volatile Organics, Base/Neutral and Acid Extractable scans were also questioned. The most significant of these were the analyses of nitrosoamines, since some of the members of this class of compounds are suspected human carcinogens. Their origin, if in fact they are present in the Refuge soils, may be a product of degradation of explosives residues. Nitrosamines were thus identified for special emphasis in the Phase II Quality Assurance Project Plan (O'Brien & Gere, November 1986). Another concern expressed by EPA was that some compounds reported as not detected may in fact be

present. Phase II analyses were conducted using greater sensitivities for most compounds in part to address this concern.

5.4.3 Phase II Data Assessment

The Phase II data validation was conducted by O'Brien & Gere using the procedures described in Section 5.4. The Phase II data validation worksheets are included in Appendix J. As a result of the data validation, data qualifiers have been assigned to the Phase II analytical results on a sample by sample basis. These data qualifiers reflect specific requirements or deviations from the QAPP. As noted in Appendix J, there were several excursions from these requirements. The major excursions were deviations from the required extraction and analysis times for the HSL organics for several samples. Of secondary concern is that the surrogate, MS/MSD recoveries, MS/MSD Relative Percent Deviation (RPD) values, and detection limits for some samples were outside the QC limits as set forth in the QAPP. An overall assessment suggests that these excursions are minimal and that the data are useable for risk assessment and evaluation of remedial alternatives.

The deviations in holding times were, at most, only a few days. These deviations in holding times will not affect greatly the levels of major contaminants observed, i.e. PCBs and lead. Volatilization or microbial degradation of these compounds during the holding time excursions is not expected to be of significance.

The situation where volatiles were quantitated below blank contamination is also minor because of the trace levels found. Approximately five percent of the samples exceeded the advisory levels of percent recoveries and RPD. These levels are only advisory and not

criteria for rejection. Therefore, these data are useable for risk assessment.

The detection limits listed in the data file are in many cases above those listed in the QAPP. Those listed in the data file are calculated based on dry weight while those listed in the QAPP reflect as received or wet weights. Although slightly high, the levels are satisfactory to define the conditions of the sites.

The data base from an overall standpoint is of sound quality and provides an accurate representation of the individual sites. A qualitative assessment, and where appropriate, a quantitative assessment of environmental effects can be derived from these data.

5.4.4 Field QA/QC

The purpose of the field QA/QC program was to assure that environmental monitoring data for this investigation would be of known and acceptable quality. The general objectives were consistent with the objectives established by US EPA CLP protocols, which are "... to provide a uniform basis for subsampling, sample handling, instrument condition, methods control, performance evaluation, and analytical data generation and reporting. " The specific field QA/QC requirements for meeting the federal protocols for CLP and non-CLP analysis for Crab Orchard samples were detailed in Table 10 of the Phase II QAPP (November, 1986).

Blanks, duplicates, and spikes were collected and analyzed as part of the field QA/QC program. Blanks were employed to ensure that neither glassware nor procedural contamination had occurred. The blanks consisted of deionized water for ground and surface water matrices, and washed/dried analytical grade sand for soil/sediment matrices. The blanks

are identified by a separate ID field (Site 42) and laboratory sample number.

Field duplicate samples were treated and packaged as separate samples, but were analyzed by the same laboratory for a given set of analytical parameters. The samples were field homogenized, divided equally, and submitted for analyses as distinct samples. Duplicate samples are identified in the sample ID listing as Site 40. The analysis results provide information as to the precision of both the analytical and sampling programs.

Spike samples were treated exactly as the field duplicates until they were received by the laboratory performing the analyses. Each laboratory used the samples designated as spikes (Site 41) and integrated them as part of their internal QA/QC samples for each batch. When no spike samples were received with a particular shipment, the laboratories prepared a laboratory spike for analyses with that particular batch.

Of a total of 1061 samples collected as part of the remedial investigation program, approximately 9% (93) were field duplicates, 7% (76) were field spikes, and 4% (44) were field blanks. The number of QA/QC samples collected met or exceeded the requirements for water/soil/sediment investigations set forth in the QAPP.

From the review of the field QA/QC analytical data, thirteen (13) out of eighty two (82) soil/sediment duplicates were reported as having concentrations at least one order of magnitude different (+/-) from their corresponding samples for at least one constituent. All of the water duplicates (11) closely matched the concentrations in their respective samples.

A review of the field spikes was completed as part of the laboratory data validation since most of the samples designated as field spikes were used as the batch spike in the laboratory when possible. The analytical data listing in Appendix I includes the qualifier 'R' for data points in which the MS/MSD results were outside of QA/QC limits.

The analytical results for the field water blanks showed trace amounts of copper (below 0.7 to 3.1 ug/L), and lead (below 1 to 6.2 ug/L). Similarly, the soil field blanks contained copper (below 0.7 ug/L to 0.77 ug/L). All other parameters were either below detection or were also detected in the laboratory blanks. A total number of 12 out of 44 blanks were reported as having parameters above the detection limits.

SECTION 6 - EVALUATION OF HUMAN HEALTH AND ENVIRONMENTAL EFFECTS

6.1 General

This section outlines the principles and approaches used to evaluate the environmental risks that may exist at the sites included in this Remedial Investigation. Two general tasks are described: 1) the identification of potential exposure pathways, otherwise known as a qualitative assessment; and 2) the quantitative risk characterization process. The overall risk characterization approach is outlined in Figure 6-1.

The assessments described in the following sections are based on the chemical, physical, biological, and toxicological properties of the waste constituents. The properties of several contaminants detected at the Refuge (cadmium, copper, chromium, cyanide, lead, nitrosoamines and PCBs) are contained in Exhibit A (Clement Associates, Inc., September 1985). These contaminants are among those addressed in the discussions of environmental effects in Sections 24, 29, 34, 35, 36 and 37.

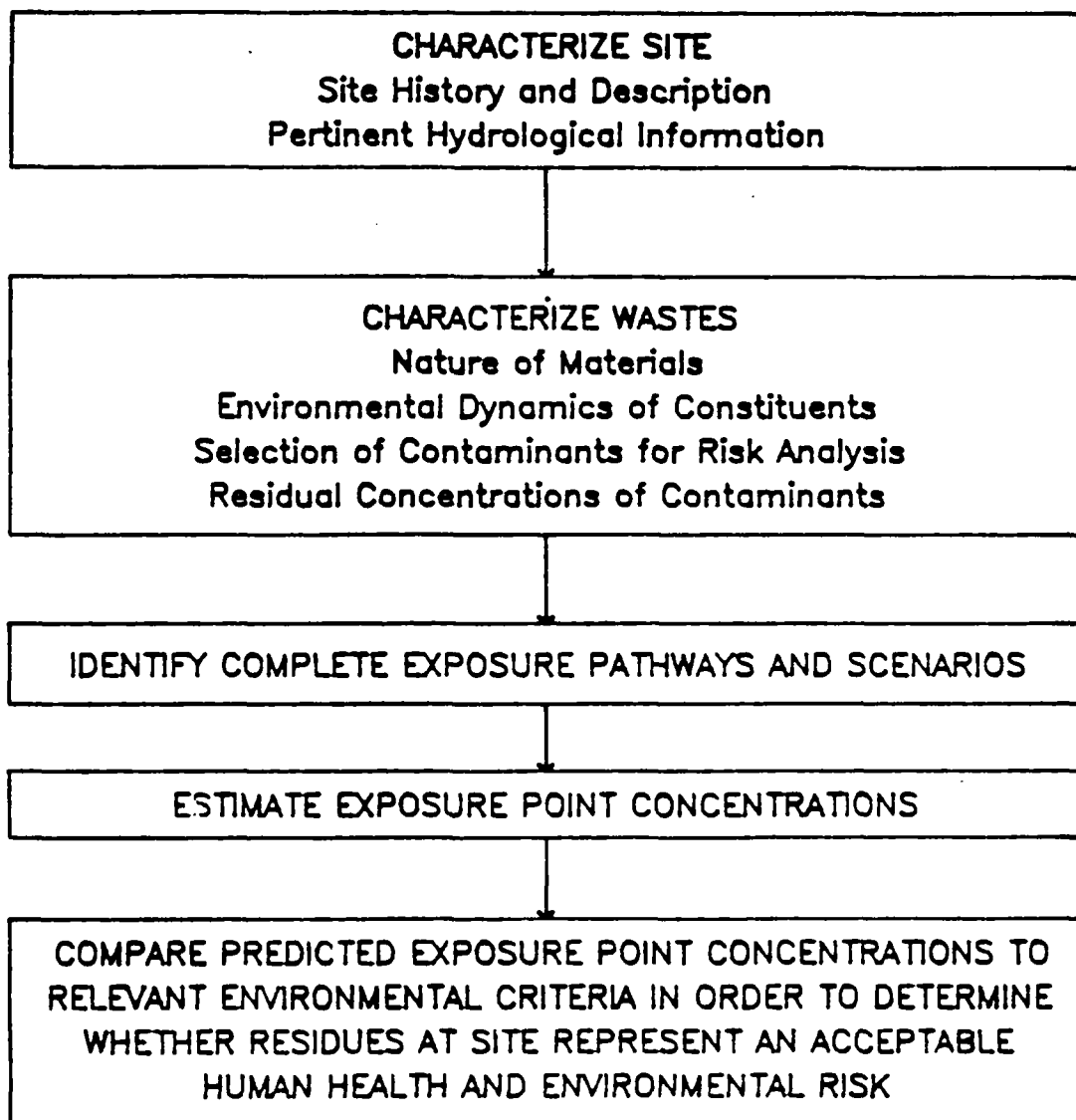
6.2 Regulatory Criteria and Standards

Wherever possible, analytical data obtained during the RI are compared to appropriate regulatory criteria or standards. With the exception of PCBs, as discussed later, no such criteria have been established for contaminant levels in soils or sediments. There are Federal and Illinois regulations governing surface waters, ground water, and fish.

These standards and criteria include: drinking water Maximum Contaminant Levels (MCLs), federally approved state water quality standards developed under the Clean Water Act (e.g. Illinois General Use Water Quality

Figure 6-1

Risk Characterization Process



Standards), EPA Health Advisories (SNARLs: Suggested No Adverse Impact Levels) and EPA Ambient Water Quality Criteria (AWQC). These standards and criteria are used as the relevant ambient concentration requirements for the protection of human health.

Samples from ponds, lake water, and ground water were compared to Federal MCLs and Illinois standards. For those parameters which are not presently regulated under these criteria, the data were compared to federal AWQC for aquatic life and for human health protection, where appropriate.

The regulations for surface water and ground water are contained in the "Illinois Water Pollution Control Rules," Illinois Administrative Code, Title 35, Subtitle C, 1972, as amended through January 1987. General Use Water Quality Standards are specified in Subpart B of this regulation, and standards for public water supplies are in Subpart C. "General use" indicates usage for aquatic life, agricultural use, primary and secondary contact, and most industrial uses. "Public water supply" indicates that the water is withdrawn for treatment and distribution as a potable supply or for food processing. Ground water in Illinois is generally classified as a public water supply.

Table 6-1 summarizes the applicable standards for general use waters and public water supplies. For the area investigated in this RI, the following water bodies are classified as general use: all tributaries to Crab Orchard Lake, and all natural ponds and impoundments throughout the Refuge. Crab Orchard Lake is used as a public water supply by the Refuge, and the investigations for Site 34 address the water quality of the Lake. Ground water at the Refuge is also classified as a public water supply. Ground water samples collected for metals analyses were filtered when possible, to represent the water quality that would be obtained if the water was withdrawn for consumption, or the fraction that could potentially migrate via the ground

TABLE 6-1
REGULATORY CRITERIA

Source: Illinois Administrative Code, Title 35, Subtitle C, 1972, as amended through January 1987.

<u>Constituent</u>	<u>General Use Water Quality Standards</u>	<u>Public and Food Processing Water Supply Standards</u>
pH	6.5 - 9.0	6.5 - 9.0
Arsenic (total)	1.0 mg/l	0.05 mg/l
Barium (total)	5.0 mg/l	1.0 mg/l
Boron (total)	1.0 mg/l	1.0 mg/l
Cadmium (total)	0.05 mg/l	0.010 mg/l
Chloride	500. mg/l	250. mg/l
Chromium (total)		0.05 mg/l
Chromium (total hexavalent)	0.05 mg/l	0.05 mg/l
Chromium (total trivalent)	1.0 mg/l	0.05 mg/l
Copper (total)	0.02 mg/l	0.02 mg/l
Cyanide	0.025 mg/l	0.025 mg/l
Fluoride	1.4 mg/l	1.4 mg/l
Iron (total)	1.0 mg/l	1.0 mg/l
Lead (total)	0.1 mg/l	0.05 mg/l
Manganese (total)	1.0 mg/l	0.15 mg/l
Mercury (total)	0.0005 mg/l	0.0005 mg/l
Nickel (total)	1.0 mg/l	1.0 mg/l
Nitrate-Nitrogen		10. mg/l
Oil (hexane-solubles)		0.1 mg/l
Pesticides/Herbicides		
Aldrin		0.001 mg/l
Chlordane		0.003 mg/l
DDT		0.05 mg/l
Dieldrin		0.001 mg/l
Endrin		0.0002 mg/l
Heptachlor		0.0001 mg/l
Heptachlor Epoxide		0.0001 mg/l
Lindane		0.004 mg/l
Methoxychlor		0.1 mg/l
Toxaphene		0.005 mg/l
Parathion		0.1 mg/l
2,4-Dichlorophenoxyacetic acid (2,4-D)		0.1 mg/l
2-(2,4,5-Trichlorophenoxy) propionic acid (2,4,5-TP or Silvex)		0.01 mg/l

TABLE 6-1
(Continued)

<u>Constituent</u>	<u>General Use Water Quality Standards</u>	<u>Public and Food Processing Water Supply Standards</u>
Phenols	0.1 mg/l	0.001 mg/l
Phosphorus	0.05 mg/l	0.05 mg/l
Selenium (total)	1.0 mg/l	0.01 mg/l
Silver (total)	0.005 mg/l	0.005 mg/l
Sulfate	500. mg/l	250. mg/l
Total Dissolved Solids	1000. mg/l	500. mg/l
Zinc	1.0 mg/l	1.0 mg/l

Toxic Substances *

- * Any substance toxic to aquatic life shall not exceed one-tenth of the 96-hour median tolerance limit (96-hr. TL₅₀) for native fish or essential fish food organisms, except for USEPA registered pesticides approved for aquatic application.

Table 6-2

FEDERAL DRINKING WATER STANDARDS
MAXIMUM CONTAMINANT LEVELS IN WATER

PARAMETER	ABBREVIATION	UNITS	MCL	MCLB	SMCL
VOLATILES & SEMIVOLATILES					
1 1,1,1-Trichloroethane	CL3CCl3	ug/L	200	200	
4 1,1-Dichloroethane	DCETAN11	ug/L			
5 1,1-Dichloroethane	DCLEN11	ug/L	7	7	
6 1,2-Dichloroethane	DCETAN12	ug/L	5	0	
14 Benzene	BENZ	ug/L	5	0	
21 Carbon tetrachloride	CCl4	ug/L	5	0	
22 Chlorobenzene	CLOROBZ	ug/L		60	
28 Ethylbenzene	ETHBENZ	ug/L		680	
33 Styrene	STYRENE	ug/L		140	
35 t-1,2-Dichloroethane	DCLEN12	ug/L		70	
37 Tetrachloroethane	CL4C2	ug/L			
38 Toluene	TOLUENE	ug/L		2000	
Total Trihalomethanes	THM	ug/L	100		
39 Total Xylenes	XYLENES	ug/L		440	
40 Trichloroethane	CL3C2H	ug/L	5	0	
43 Vinyl chloride	CH2CHCL	ug/L	2	0	
110 Pentachlorophenol	PNCLPHOL	ug/L		220 #	
PESTICIDES/PCBs					
236 2,4-Dichlorophenoxyacid	H24-D	ug/L	100	70	
237 2,4,5-TP Silvex	H245-TP	ug/L	10	52	
134 Endrin	ENDRIN	ug/L	0.2		
137 Gamma-BHC (Lindane)	LINDANE	ug/L	4	0.2	
140 Methoxychlor	METHOXYCR	ug/L	100	340	
141 Toxaphene	TXPHENE	ug/L	5		
227 Total PCB Aroclors	TPCBAR	ug/L		0	
METALS					
160 Arsenic	AS	mg/L	0.05	0.05	
162 Barium	BA	mg/L	1	1.5	
166 Cadmium	CD	mg/L	0.01	0.005	
170 Chromium	CR	mg/L	0.05	0.12	
174 Copper	CU	mg/L		1.3	1
176 Iron	FE	mg/L			0.3
178 Lead	PB	mg/L	0.05	0.02 #	
182 Manganese	MN	mg/L			0.05
184 Mercury	HG	mg/L	0.002	0.003 #	
190 Selenium	SE	mg/L	0.01	0.045 #	
192 Silver	AG	mg/L	0.05		
202 Zinc	ZN	mg/L			5
INDICATORS					
231 Chloride	CL	mg/L			250
216 Fluoride	F	mg/L	4	4	2
217 Nitrate Nitrogen	NO3N	mg/L	10	10	
218 Nitrite Nitrogen	NO2N	mg/L		1	
219 PH	PH	su.	6.5-8.5		6.5-8.5
233 Sulfate	SO4	mg/L	250		250
235 Total Dissolved Solids	TDS	mg/L	500		500

NOTES:

* Potential MCL, Federal Register - March 4, 1982

Proposed MCLG

water table. Maximum contaminant levels (MCLs), Maximum contaminant level Goals (MCLGs), and Secondary MCLs (SMCLs) for a broader list of parameters are included as Table 6-2. This table was generated from regulatory criteria established or proposed by EPA, published in the Federal Register.

Ambient water quality criteria for protection of human health and aquatic life have been listed in Table 6-3. The criteria, established by the U.S. EPA (EPA 440/5-86-100, updated through Sept. 1986), are based on: a) use for which the body of water is to be protected or designated (such as recreation, agriculture, or fish and wildlife); and b) a qualitative pollutant concentration limit which will support that use. Since methods do not exist that establish a threshold for carcinogenic effects, the U.S. EPA recommends that the concentration of known carcinogens be zero for maximum human health protection. However, because zero levels of concentration may be unfeasible in many situations, a maximum target risk level was established. For example, one criterion may indicate that exposure to a carcinogen through the lifetime daily consumption of water and edible aquatic organisms could result in one additional case of cancer in a population of 1,000,000 at a concentration of 0.1 ug/L (10^{-6} cancer risk), and one additional cancer risk in a population of 100,000 at a level of 1.0 ug/L (1×10^{-5} cancer risk). The criteria listed in Table 6-3 reflect the risk level targeted by the U.S. EPA for carcinogens or 10^{-6} , for the protection of human health. The ambient water quality criteria for aquatic life shows an average concentration which should not be exceeded during any 24 hour period, and a maximum concentration which is based on the value for chronic toxicity to aquatic organisms.

Environmental contamination of food fish with PCBs is regulated under Sections 402(a) and more specifically, Section 406, "Tolerances for Poisonous Ingredients for Food", of the amended Food, Drug, and Cosmetic Act of 1938,

TABLE 6-3 (Page 3)

FEDERAL AMBIENT WATER QUALITY CRITERIA

		SELECTED PARAMETERS FROM SEPT. 1986 MHC		
		Freshwater Aquatic Life		Human Health
PARAMETER	UNITS	24 Hr Avg Chronic	Max Conc. Acute	Water and Fish Consumption
Endosulfan	ppb	0.056	0.22	7.40E+01
Endrin	ppb	0.0023	0.18	1.00E+00
Gamma-BHC (Lindane)	ppb	0.08	2	1.86E-02 #
Guthion	ppb	0.01		
Heptachlor	ppb	0.0038	0.52	2.80E-04 #
Malathion	ppb	0.1		
Methoxychlor	ppb	0.03		1.00E+02
Mirex	ppb	0.001		
Parathion	ppb	0.04		
Polychlorinated Biphenyls	ppb	0.014	2	7.90E-05 #
Toxaphene	ppb	0.013	1.6	7.10E-04 #
METALS & OTHERS				
Antimony	ppb	1,600*	9,000*	1.46E+02
Arsenic	ppb			2.20E-03 #
Arsenic (Pent)	ppb	48**	850**	
Arsenic (Tri)	ppb	390**	360**	
Barium				1.00E+03
Beryllium	ppb	5.3**	130**	6.80E-03 #
Cadmium	ppb	1.1*	3.9*	1.00E+01
Chromium VI	ppb	11	16	5.00E+01
Chromium III	ppb	210*	1,700*	1.70E+05
Copper	ppb	12*	18*	
Iron	ppb	1000		3.00E+02
Lead	ppb	3.2*	82*	5.00E+01
Manganese	ppb			5.00E+04
Mercury	ppb	0.012	2.4	1.44E-01
Nickel	ppb	96*	1,800*	1.34E+01
Selenium	ppb	35	260	1.00E+01
Silver	ppb	0.12	4.1*	5.00E+01
Thallium	ppb	40**	1,400**	1.30E+01
Zinc	ppb	47	320*	
Cyanide	ppb	5.2	22	2.00E+02

* Hardness Dependent Criterion (100 mg/l used)

** Lowest Observed Effect Level (freshwater aquatic life)

ND Insufficient data to develop criterion

Human Health Criteria for Carcinogens Reported for 10E-6 Level

as amended through 1987. This latter section allows for the establishment of "tolerances" or action levels for "unavoidable" environmental contaminants (including potential carcinogens) by the Center for Food Safety and Applied Nutrition of the Food and Drug Administration (FDA). Considerations entering into the tolerance level include an assessment of the risk posed by the contaminant, availability of suitably sensitive analytical techniques for monitoring, and economic considerations. The FDA risk assessment typically employs examination of available animal test data, using no-observed-effect levels and appropriate margins of safety to derive acceptable daily intakes for threshold toxins or unavoidable environmental carcinogens such as aflatoxins in peanuts. Food found by the FDA's nationwide monitoring network to be in excess of the established tolerance is considered to pose a potential risk to health and can be removed from the marketplace. At present, the established FDA tolerance for PCBs in food fish is 2 mg/kg in the edible tissues (previously 5 mg/kg), and for mercury the tolerance level is 1 mg/kg. There are no FDA tolerance levels for cadmium or lead.

The Toxic Substances Control Act of 1976 (TSCA) was enacted by Congress in order to consolidate regulation of commercial chemicals (of which there are at least 100,000) which do not fall under the regulatory jurisdiction of other congressional acts (i.e. the Food, Drug, and Cosmetic Act, or the Federal Insecticide, Fungicide, Rodenticide Act, etc.), but which may pose an unreasonable risk of injury to health or the environment from production, use or disposal. One of the most significant provisions of TSCA, Section 6(e)(2), mandates the U.S. EPA to eliminate the manufacture, processing, commercial distribution, and use of any PCBs except under totally enclosed conditions, with only certain exceptions. This action was taken due to the widespread environmental dissemination of this persistent, bioaccumulative, and potentially

TABLE 6-3 (Page 1)

FEDERAL AMBIENT WATER QUALITY CRITERIA

SELECTED PARAMETERS FROM SEPT. 1986 WQC				
		Freshwater Aquatic Life		Human Health
PARAMETER	UNITS	24 Hr Avg Chronic	Max Conc. Acute	Water and Fish Consumption

VOLATILES				
1,1,1-Trichloroethane	ppb			1.84E+04
1,1,2,2-Tetrachloroethane	ppb	2,400**		1.70E-01 #
1,1,2-Trichloroethane	ppb	9,400**		6.00E-01 #
1,2-Dichloroethane	ppb	20,000**	118,000**	9.40E-01 #
Benzene	ppb		5,300**	6.60E-01 #
Carbon tetrachloride	ppb		35,200**	4.00E-01 #
Chlorinated benzenes	ppb	50**	250**	4.88E+02
Chlorinated naphthalenes	ppb		1,600**	
Chloroform	ppb	1,240**	28,900**	1.90E-01 #
Dichloroethylenes	ppb		11,600**	3.30E-02 #
Dichloropropanes	ppb	5,700**	23,000**	
Dichloropropenes	ppb	244**	6,060**	8.70E+01
Ethylbenzene	ppb		32,000**	1.40E+03
Monochlorobenzene	ppb			4.88E+02
Tetrachloroethanes	ppb		9320**	
Tetrachloroethene	ppb	840**	5,280**	8.00E-01 #
Toluene	ppb		17,500**	1.43E+04
Trichloroethene	ppb	21,900**	45,000**	2.70E+00 #
Vinyl chloride	ppb			2.00E+00 #
.				
SEMI-VOLATILES				
1,1,1 Trichloroethane	ppb			1.84E+01
1,2-Diphenylhydrazine	ppb		270**	
2,4,5-Trichlorophenol	ppb			2.60E+03
2,4,6-Trichlorophenol	ppb	970**		1.20E+00 #
2,4-Dichlorophenol	ppb	365**	2,020**	3.00E+03
2,4-Dimethylphenol	ppb		2,120**	
2,4-Dinitro-o-cresol	ppb			1.34E+01
2,4-Dinitrophenol	ppb			7.00E+01
2,4-Dinitrotoluene	ppb	230**	330**	1.10E-01 #
2-Chlorophenol	ppb	2,000**	4,380**	
3,3-Dichlorobenzidine	ppb			1.00E-02 #
4-Chloro-3-Methylphenol	ppb		30**	
Acenaphthene	ppb	520**	1,700**	
Acrolein	ppb	21**	68**	3.20E+02
Acrylonitrile	ppb	2,600**	7,550**	5.80E-02 #
Benzidine	ppb		2,500**	1.20E-04 #
Bis (chloromethyl) ether	ppb			3.76E-06 #
Bis (2-chloroethyl) ether	ppb			3.00E-02 #
Bis (2-chloroisopropyl) ether	ppb			3.47E+01
Bis (2-ethylhexyl) phthalate	ppb			1.50E+04
Chloroalkyl Ethers	ppb	238,000**		

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TABLE 6-3 (Page 2)

FEDERAL AMBIENT WATER QUALITY CRITERIA

PARAMETER	UNITS	SELECTED PARAMETERS FROM SEPT. 1986 WQC		
		Freshwater Aquatic Life		Human Health
		24 Hr Avg Chronic	Max Conc. Acute	Water and Fish Consumption
Dichlorobenzenes	ppb	763**	1,120**	4.00E+02
Diethylphthalate	ppb			3.50E+05
Dimethyl phthalate	ppb			3.13E+05
Di-n-butyl phthalate	ppb			3.50E+04
Dinitrotoluenes	ppb	230**	330**	
Diphenylhydrazine	ppb			4.20E-02
Fluoranthene	ppb		3,980**	4.20E+01
Hexachlorobenzene	ppb			7.20E-04 #
Hexachlorobutadiene	ppb	9.3**	90**	4.50E-04 #
Hexachlorocyclopentadiene	ppb	7**	5.2**	2.06E+02
Hexachloroethane	ppb	540**	980**	1.90E+00
Isophorone	ppb		117,000**	5.20E+03
N-nitrosodibutylamine	ppb			6.40E-03 #
N-nitrosodimethylamine	ppb			1.40E-03 #
N-nitrosodiphenylamine	ppb			4.90E+00 #
N-nitrosopyrrolidine	ppb			1.60E-02 #
Naphthalene	ppb	620**	2,300**	
Nitrobenzene	ppb		27,000**	1.98E+04
Nitrophenols	ppb	150**	230**	
Nitrosamines	ppb		5,850**	8.00E-04 #
Pentachloroethane	ppb	1,100**	7,240**	
Pentachlorobenzene	ppb			7.40E+01
Pentachlorophenol	ppb	3.2**	55**	1.01E+03
Phthalate ethers	ppb	3**	940**	
Phenol	ppb	2,560**	10,200**	3.50E+03
Polynuclear Aromatic Hydrocarbons	ppb			2.80E-03 #
Tetrachlorinated Ethanes	ppb		9,320**	
Trichlorinated Ethanes	ppb		18,000**	
PESTICIDES/PCB				
2,4-D	ppb			1.00E+02
2,4,5-TP	ppb			1.00E+01
4,4'-DDT	ppb	0.001	1.1	2.40E-05 #
DOE	ppb		1050**	
TDE	ppb		0.6**	
Aldrin	ppb	ND	3.0	7.40E-05 #
Alpha-BHC	ppb			9.20E-04 #
Beta-BHC	ppb			1.62E-02 #
BHC	ppb		100**	
Chlordane	ppb	0.0043**	2.4**	4.60E-04 #
Demeton	ppb	0.1		
Dieldrin	ppb	0.0019	2.5	7.10E-05 #
Dioxin	ppb	LT 0.00001**	LT 0.001**	1.30E-08 #

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toxic class of compounds. In the ensuing ten years since TSCA was enacted, the U.S. EPA Administrator has promulgated and finalized rulemaking pursuant to this section of TSCA.

With regard to spills of PCBs, the U.S. EPA policy (40 CFR 761 Subpart G) states that spills resulting in contamination at or exceeding levels of 50 parts per million (ppm) require immediate notification and initiation of cleanup within 24 hours. Other provisions of the policy require decontamination of soil in nonrestricted access areas to a 10 ppm level, and cleanup in restricted areas to a 25 ppm level. Low contact outdoor surfaces and low contact indoor surfaces shall be cleaned to 10 micrograms per square meter. Standards for spills to surface waters, drinking water, grazing land and vegetable gardens will be set by EPA case-by-case. Additional relevant standards and guidelines for drinking water and ambient air are listed in the report, Development of Advisory Levels for PCBs Cleanup, U.S. EPA, May 1986.

Nitrosoamines were detected at several sites within the Refuge, and it is speculated that their presence may be derived from the degradation of explosives residuals. The levels detected (0.021 to 3.58 mg/kg in 16 of 33 study sites) are qualitatively reliable although quantitatively estimated due to insufficient QA/QC support data. These levels are significant due to concerns that nitrosoamines might be carcinogenic in humans and wildlife. However, several studies on toxic effects from these compounds have been related to exposure to nitrosoamines in the water phase, since they generally exhibit a low log octanol/water partition coefficient and extensive sorption to particulates is unlikely (see Exhibit A). The detectable concentrations of diphenyl and dimethyl nitrosoamines at Crab Orchard Refuge were all associated with soil/sediment matrices. A quantitative risk assessment to address the risk associated with nitrosoamines is presented for Sites 12 and 19 (Sections 19 and

26), as the highest concentrations of the diphenyl isomer was detected at Site 12, and the highest concentration of the dimethyl isomer was detected at Site 19. For other sites where nitrosoamines were detected at lower levels, a qualitative risk assessment is presented, comparing the levels of risk to those discussed under Sites 12 and 19. The cumulative toxicity due to the presence of nitrosoamines at sites where other potential carcinogens may be present have been estimated by adding the risk from nitrosamines to the risk posed by the other contaminants, if any, at the site. To account for the uncertainty in the quantitation of these compounds from the Phase I investigation, a factor of two (2) times the measured analytical result has been used in this report to estimate the quantitative risk from nitrosoamines.

The standards or criteria used as a first basis for comparison for other contaminants found at the Refuge such as lead, cadmium, chromium, mercury, and cyanide included applicable Federal and Illinois State standards for waters. For soil/sediment matrices, for which no standards exist, the concentrations of these parameters were discussed in reference to the levels detected at the two control sites included in this investigation. Section 8.0 presents the characterization results for the control sites. Section 8.4 and Table 8-1 discuss the levels of different inorganic and organic constituents typical in Refuge soils. In addition, the concentrations of inorganic parameters in soils were compared to typical values for U.S. soils, based on studies reviewed in the literature. Organic parameters, when detected, are discussed in the subsections for 'Environmental Effects' for each site.

6.3 Qualitative Assessment

A hazardous chemical may represent human or environmental risks only if humans, animals, wildlife or sensitive ecosystems have the potential to be

exposed to (i.e. contact) the material in sufficient quantity to affect either the health of the individuals or the general ecological balance. Exposures to the wastes can occur in numerous ways. Examples of potential exposure scenarios related to an uncontrolled hazardous waste site may include the following:

- Ingestion of surface water or ground water containing solubilized contaminants or ingestion of contaminated surface water sediments.
- Inhalation of volatile contaminants or contaminants airborne in association with particulates.
- Ingestion of biota (e.g. fish) which have bioaccumulated a contaminant released from the waste site.
- Dermal absorption or ingestion of contaminated materials resulting from direct contact with the source of materials at the waste site.

Four basic pathways of exposure are addressed: air, surface water, ground water and direct contact. Each of these exposure pathways may have one or more exposure scenarios associated with them. Although it may be possible to postulate numerous hypothetical scenarios of exposure for each of the basic exposure pathways, a "complete" exposure scenario (i.e. one potentially posing a risk) must include the following components:

1. A waste source and a mechanism of release from it. Examples of release mechanisms include volatilization, wind scour, surface runoff and leaching.
2. A viable transport mechanism (air, surface water, or ground water) from the waste source to a potential receptor point.
3. A potential receptor population (humans, plants or wildlife) or location (i.e. sensitive ecosystem) for a contaminant released and transported from the waste source.

4. An exposure and uptake route (inhalation, ingestion, or dermal absorption); i.e. a mechanism by which the receptor absorbs the contaminant allowing it to exert its toxic effect.

If any one or more of these components are missing, an exposure scenario is by definition incomplete and, therefore, poses no risk to health or the environment. The one exception is the direct contact exposure pathway, a transport mechanism not necessarily involved, since the source is contacted by a receptor. Exposures to humans or terrestrial wildlife populations by direct contact may occur via contact with exposed soil or waste residues or by burrowing or excavation to expose subsurface residues.

Important release mechanisms and exposure routes for each of the four basic exposure pathways are described in Table 6-4.

In some instances, contaminant concentrations are well below appropriate action levels such that a quantitative assessment may not be required to conclude that the contaminant does not pose a health or environmental risk. Generally, however, a quantitative risk assessment is performed for all 'complete' exposure pathways if contaminant residues potentially pose a risk of exposure, regardless of whether appropriate action levels are exceeded. The approach to quantitative risk assessment is discussed in the following section.

6.4 Quantitative Assessment

Quantitative risk characterization is carried out only for potentially "complete" exposure pathways and their identified scenarios. The risk characterization process used in this assessment involves three steps: 1) selection of waste constituents to serve as indicators of the potential environmental and health significance of the waste; 2) the prediction of exposure point concentrations at receptor locations; and 3) the comparison of

TABLE 6-4

GENERAL CONTAMINANT RELEASE MECHANISMS
AND
EXPOSURE ROUTES

<u>Exposure Pathways</u>	<u>Mechanisms of Release From the Waste Source</u>	<u>Exposure Routes</u>
Air	Contaminated dusts Volatilization of contaminants	Inhalation Inhalation
Surface Water	Site runoff (dissolved and suspended load) Site leaching followed by ground water seepage	Ingestion, inhalation, dermal absorption Ingestion, inhalation, dermal absorption
Ground Water	Site leaching	Ingestion, inhalation, dermal absorption
Direct Contact	Contact with contaminated soils Contact with contaminated flora and fauna Secondary human contact	Ingestion, inhalation, dermal absorption Ingestion, inhalation, dermal absorption Ingestion, inhalation, dermal absorption

the predicted exposure point concentrations with relevant action levels to establish whether the waste represents an unacceptable risk to human health, aquatic life, wildlife, or the environment.

Indicator chemicals for use in the quantitative exposure analysis are selected based on a "waste characterization" which considers 1) the nature and history of the waste material and 2) the environmental dynamics and the toxicology of the waste's constituents. Predicted exposure point concentrations are then generated for each selected indicator chemical. Site specific data for each indicator chemical and conservative modeling procedures depicting reasonable "worst case" scenarios are used in generating the predictions. Finally, the predicted exposure point concentrations for each indicator species are compared to the relevant action levels for the protection of human health, aquatic life or wildlife. Regulatory criteria used as basis for comparison are described in Section 6.2.

In those cases where contaminant concentrations in the complete exposure pathways do not exceed appropriate action levels, or those for which no standards exist, a qualitative risk assessment is performed to evaluate the potential for exposure to humans or wildlife. A quantitative assessment may or may not be necessary depending on the results of the qualitative assessment. If the concentrations exceed the criteria used as a basis for comparison, both qualitative and quantitative assessments are prepared. The remedial actions for the FS, if needed, are then based on the results of this risk-based evaluation.

When a quantitative assessment is required, exposures are quantified for all active exposure routes (e.g., diet, drinking water, inhalation, or dermal absorption) to determine intakes for acute, subchronic, and chronic lifetime exposures by the receptor. For carcinogens, unit risk factors generated from

animal test data using recently promulgated guidelines for performing risk assessments of carcinogens (USEPA/ICF, May 1985) are combined with intake data to derive a quantitative estimate of the incremental cancer risk. This value is compared to site circumstances, magnitude of exposed receptor populations, and other factors in order to determine the acceptability of the exposures for non-carcinogens (i.e. reproductive toxins, organ and systemic toxins). Acceptable daily intakes established by the USEPA or other agencies are evaluated for comparison to estimated exposure levels under acute, subchronic, and chronic conditions. Again, if these values have not been generated, appropriate animal test data are used, if available, determining "no observed adverse effect" levels and using appropriate margins of safety in order to determine the potential for health risks to exposed receptors at the estimated intake levels.

In the event that several carcinogenic contaminants are present at a site, the calculated risks to humans or wildlife are added to determine the cumulative risk level. For noncarcinogens acting by similar toxic mechanisms, exposure levels relative to the acceptable daily intakes are added to determine if an overall acceptable daily intake is exceeded. An example is illustrated in the assessment developed for Site 17 (Section 24.4); additive risks were not applicable for any other sites at the Refuge. This procedure might be used even if the concentrations of the individual constituents are below the corresponding standards or criteria.

In cases where action levels or standards have not been established, an evaluation to determine the potential health risks to receptors is performed. There are a number of circumstances under which such an evaluation may be necessary. For instance, the existing data base may indicate that the material is essentially innocuous at any reasonable environmental concentration.

Conversely, there may be insufficient data to establish an action level. In these cases, attempts are often made to identify a chemically analogous compound with adequate toxicity data in order to qualitatively characterize the hazardous properties and potential risks of the contaminant in question. In cases where the compound has associated toxicological concerns but no action levels have been set by regulatory agencies, the quantitative risk assessment is initiated by deriving scientifically sound acceptable intake levels and carcinogenicity risk factors (if appropriate), followed by a quantitative risk estimation as described above. In addition, for non-human receptors, risk at a site may be estimated by site bioassays and/or histopathological examination of indicator species collected from the site.

6.5 Analysis of Uncertainties

Procedures employed in the derivation of environmental criteria and standards for environmental contaminants and in performance of case-specific quantitative risk assessments have historically been extremely conservative in order to be most protective of public health and the environment in the face of a broad spectrum of scientific and case-specific uncertainties. As a result, assumptions and estimates, and data inputs selected for quantitative risk assessments generally tend towards the "worst case scenario" for exposure, hazard evaluation, and choice of models for risk estimates. While there is nothing inherently invalid with this approach from either scientific or regulatory perspectives, it is important to recognize that the collective uncertainty and subsequent conservative estimates can result in "worst case" estimates which can be far removed from the most probable "real world" or site-specific situation.

The following is a brief and by no means exhaustive enumeration of some of the areas of uncertainty most frequently encountered in exposure and risk characterization.

- Exposure:

- a. The environmental chemistry of waste site contaminants is often poorly defined. In the absence of persistence or dissipation data (re: biological and chemical degradation, or volatilization tendencies, etc.) in the appropriate media (soil, surface and ground water, air), assumptions for exposure estimates are often made concluding that degradation does not occur, when it very well may at the site in question. The lower tendencies for transport by volatilization or solubilization of the contaminants found at the Refuge including PCBs, explosives, lead, and other metals, which tend to adsorb on the silty clay soils typical of the site may not be recognized.
- b. Due to insufficient site analysis, estimates concerning the velocity of vertical and horizontal movement of a contaminant plume in the unsaturated and saturated zones are often made ignoring the very important retarding influence which contaminant partitioning to soil organic matter may have. By equating contaminant velocity with ground water velocity, potential important destructive mechanisms are largely negated. On the other hand, the presence of solvents in the soil could enhance the transport of normally immobile substances such as PCBs.
- c. Knowledge on the systemic absorption of contaminants under various conditions is typically uncertain. For example, the bioavailability of soil or dust-bound contaminants via ingestion or dermal and inhalation exposure is still scientifically uncertain, particularly for

contaminants with high adsorption coefficients. Similarly, in aquatic systems, the propensity of sediment-adsorbed contaminants to bioaccumulate and produce food chain magnification, or induce toxicity in the absence of measurable residues in the free water column is largely a function of the physical properties of the contaminant, and the exposure medium. Benthic organisms can potentially be impacted by sediment bound contaminants, especially if the contaminant can desorb to some degree and establish locally significant water concentrations in the interstitial spaces of bottom sediments.

- d. Assumptions concerning intentional or unintentional dietary exposures to site contaminants are often made without knowledge of the contributions of various sources (i.e. fish and game, predator species, vegetation, locally grown vegetables) to local human and wildlife populations. Furthermore, groundwater is often equated with potable water, which can be an invalid assumption in many areas.
- e. Crab Orchard National Wildlife Refuge represents a vast and diverse habitat for both terrestrial and aquatic biota, as well as providing a wide range of recreational opportunities for humans. As described later in this report, a number of sites exist within the Refuge which contain residues of waste materials which may present the possibility for multiple exposures. In the risk assessments which follow, exposure risks are considered on a site-specific basis only, because there is no reasonable quantitative method to determine, for example, how frequently an individual hiker might traverse a given area with potential exposure to one waste component, and at some different

time become exposed in a different area to the same or a different waste constituent. A similar potential exists for fish and wildlife. Mobile animals such as deer and birds, as well as fish, which are relatively free to move from area to area, potentially receive diverse exposures of varying types and degree. By the same reasoning, mobile species may also spend most of their lives in non-contaminated areas, a high probable situation given the relative abundance of non-industrial areas on the Refuge.

In order to deal with this uncertainty, exposure scenarios were constructed with a worst case approach for both human and wildlife risk assessments. For humans, repeated visits to specific sites were assumed to occur over at least a portion of the individual's lifetime, with upper case values for exposure assumed. With wildlife, lifetime exposures were modeled for smaller and less mobile wildlife species (ie. rodents, resident birds) spending all or most of their life time living within the confines of a specific area. Exposures to more mobile species were somewhat adjusted in consideration of differences in habits (burrowing seed-consuming mice vs. free-ranging, browsing deer), relative to the resident species. It was felt that this approach would adequately model the worst case exposures of humans and mobile wildlife at the Refuge, regardless of whether the exposures were produced from individual exposures at a variety of sites, many exposures at a specific site, or some combination thereof.

Hazard and Risk Assessment:

Due to the generally inadequate data base on the effects of contaminants on human and aquatic wildlife populations, data on the toxic

effects of these materials are generally taken from controlled tests with laboratory animals. Dose-response data from these tests are then extrapolated using "uncertainty factors" (margins of safety) to derive acceptable exposure levels for threshold toxins or, in the case of presumed non-threshold toxins (carcinogens), data are entered into biostatistical models to derive estimates of incremental risks of disease resulting from expected lifetime exposures. Since it is held by regulatory groups that there are no safe exposures to a carcinogen (all exposure levels carry some risk of cancer), margins of safety are not appropriate. Instead, an upper bound estimate of the dose-tumor response relationship is used for extrapolation. Also, lifetime exposures of humans vs. animals are considered to be equivalent. Physiologically, a 2-year old mouse is considered to be roughly equivalent to a 70-year old human. Therefore, extrapolation of lifetime exposures based on the effects to laboratory animals is typically used in the evaluation of risks to humans.

The results of the biostatistical model are employed by various regulatory agencies. This entire process contains many stages for introduction of uncertainty, as discussed below.

- a. For practical purposes, laboratory animals such as rats, mice, rabbits, dogs, etc. are used to generate dose-response data. Extensive research on the toxicity of PCBs to minks and ferrets, conducted by researchers at Michigan State, has also been used in this report in the development of environmental effects. It is generally assumed that these animals respond qualitatively similar to humans or to the receptor at risk for the entire range of acute, subchronic, and chronic toxic effects, and that quantitative

differences can be controlled with the use of uncertainty factors in standard setting. Exceptions to this assumption are numerous.

- b. Dose-response data can be profoundly affected by inaccuracies in data measurement. While current toxicity data are typically generated under a system of good laboratory practices, many standards are set based on older studies which have insufficient reporting data to verify the accuracy of such key elements as animal body weight, identity, composition, stability of the test material, and verification of the delivered dosage. Interpretation of pathology data can also introduce uncertainty. For instance, the use of chemically-induced liver nodules in rodents to predict human cancer is highly controversial.
- c. Due to the limited toxicological data base, and the variations of response between species and between members of human and animal populations, "uncertainty factors" or margins of safety, are typically employed to set conservatively acceptable intake levels of threshold toxins. For instance, a ten-fold factor is used to extrapolate a no observed effect dose level (NOEL) from animals to humans or to potentially more sensitive animal populations. Another factor of ten is used to account for the most sensitive elements of the human population. If a NOEL is not available, a lowest observed effect level (LOEL) is often used with an additional factor of ten to derive an acceptable intake. Finally, subchronic exposure data have been employed to predict chronic effects with an additional ten-fold factor. Thus, regulatory standards with uncertainty of 10,000, (or more) have been established.

d. In performing life-time carcinogenesis bioassays in rodents, logistical and economic constraints limit the numbers of animals that may be tested. Relatively high dosages are often employed to increase the sensitivity of predicting a carcinogenic effect. Using one or more biostatistical models, the dose-response data are extrapolated to human populations exposed to low-level lifetime levels of the contaminant in order to estimate the risk of excess cancer in the population. The most commonly used-model, the linearized multistage model, assumes a linear dose-response relationship in the quantitatively undefined low dose region and that the cancer is produced by a multiple step process initiated by a somatic gene mutation. There is accumulating evidence that while these conservative models may be acceptable from a regulatory standpoint, the biological basis for their use may be uncertain in many cases. In particular, it appears that many contaminants of concern at waste sites, such as large, lipophilic and relatively inert compounds such as PCBs, are inactive in producing the kinds of mutagenic events assumed in the multistage model. It has been hypothesized that the carcinogenic effects produced by these compounds in animals, especially in the liver, may occur by promoting preexisting lesions at the high dosages tested. Thus, it is possible that a threshold exists for carcinogenicity by these types of compounds and that the linear model may be inappropriate for estimating risks to potential receptors.

Other areas of uncertainty exist in determining cancer risks arising from waste constituents. Assumptions of life-time exposures must be validated on a case-by-case basis. Also, while increments

of lifetime cancer risk of 10^{-6} to 10^{-5} may have significance on a national basis, the significance of exposure of a limited, site-specific population should be addressed and justified. The validity of the data used in the evaluation of risks also introduces additional uncertainty dependent on the quality of the laboratory analyses. Finally, while current regulatory approaches to risk assessment of carcinogens and threshold toxins provide guidelines for exposures to mixtures of waste components, application of these guidelines require detailed knowledge on the potential synergistic and antagonistic interactions of the components, as well as their basic mode of toxic action. Such information is frequently lacking.

Summarizing, there is a wide level of uncertainty and variability in performing site-specific quantitative risk assessment. While often non-quantifiable in general terms, the key uncertainty factors should be understood and addressed when deriving risk estimates on a site-specific basis and when analyzing regulatory standards.

SECTION 7 - PRELIMINARY REMEDIAL ALTERNATIVES EVALUATION

7.1 Remedial Response Objectives

Following the compilation of information regarding site conditions, identification and quantification of hazards, pathways, and potential receptors from the RI, the objectives of the remedial responses can be developed. Similar to the evaluation of environmental and human effects (Section 6), the remedial effort addresses four pathways of exposure including surface water, ground water, air, and direct contact. For the objectives within each pathway, criteria are identified to determine whether or not the objective is met. In general, the objectives of the remedial responses are to mitigate, reduce, or eliminate contaminant transport, and to prevent or minimize exposure or risk to humans, wildlife, and the environment.

A more complete identification of objectives and evaluation of remedial alternatives will be included as part of the Feasibility Study. The complete statement of objectives will delineate the general and specific components of each site to be controlled. Those objectives will also be based on public health and environmental concerns, the results of the RI, and applicable or relevant and appropriate Federal or State requirements (ARARs) as defined in SARA.

This report presents a preliminary review of the remedial investigation results to identify the presence of an adverse environmental impact, and the potential need for remediation. This report also includes a preliminary review of response actions which may be applicable for each site. (See Sections 9.5-39.5)

7.2 Preliminary Remedial Technologies

In order to propose preliminary solutions which could be implemented at a given site, a list of potentially feasible remedial technologies was developed. Each remedial response alternative includes a response action as well as associated remediation technologies.

Remedial response actions and technologies that will be considered for each site include, but are not limited to one or a combination of the following:

<u>Response Action</u>	<u>Potentially Feasible Remedial Technologies</u>
1. No Action	Monitoring, Fencing, Site Use Limitations
2. Containment	Dams, Ground Water Barriers, Bulkheads, Capping, Sealing
3. Pumping	Ground or Surface Water Pumping, Sediment Dredging
4. Collection	Sedimentation Basins, Subsurface Drains, Gas Vents, Gas Collection
5. Diversion	Dikes, Berms, Grading, Stream Diversion, Ditches, Terraces, Chutes, Downpipes
6. Complete Removal	Excavation of Wastes, Soil/Sediment; Tanks, Drums, Liquid Wastes
7. Partial Removal	Selected Excavation of Wastes, Soil/Sediment, Tanks, Drums, Liquids

8. On-Site Treatment	Biological, Chemical or Physical Treatment, Incineration, Solidification, Land Treatment, Vitrification
9. Off-Site Treatment	Treatment/Storage/Disposal Facility, Incineration, Solidification, Vitrification
10. In-Situ Treatment	Permeable Treatment Beds, Bio-Reclamation, Neutralization, Landfarming
11. Storage	Temporary Structures
12. On-Site Disposal	Landfill, Land Application
13. Off-Site Disposal	Landfill, Surface Impoundments, Land Application
14. Alternative Water Supply	Cisterns, Above Ground Tanks, Deeper/Upgradient Wells, Municipal Water, Relocation of Intake, Specific Treatment Devices
15. Relocation	Temporary/Permanent Relocation of Animal Populations

The technologies identified above will be screened during the FS based on several criteria outlined in the NCP including: a) applicability to site conditions; b) effectiveness in reducing toxicity, mobility or volume of the contaminants in the matrices of contamination; c) feasibility; d) reliability; and d) proven effectiveness when used under similar circumstances. A preliminary screening of remedial technologies may eliminate or modify those technologies that do not apply to site conditions, are ineffective for the required treatment

task, are infeasible to implement, are far more costly than alternatives that provide the same result, require unreasonable time periods for completion, or rely on insufficiently developed technology. Applicable innovative alternative technologies will be identified and evaluated in the FS, and will be carried through the preliminary screening if there is reasonable belief they offer a significant advantage in the form of treatment performance, ease of implementation, fewer or lesser adverse impacts, or lower cost.

Potential remedial response actions and technologies for each Refuge site studied in this investigation are discussed in Sections 9 through 39, Preliminary Remedial Alternatives Subsections of this report.

7.3 Remedial Alternatives

The product of the preliminary screening of technologies will be the identification of potentially suitable technologies, including innovative treatment technologies that may offer advantages over conventional remedies. These technologies will be assembled, during the FS, into a range of distinct alternative management strategies which address the preliminary objectives at each site requiring remedial actions.

Remedial alternatives will be developed for three categories of management strategies. Typically, there will be more than one alternative developed for the category that employs, as its principle element, treatment that reduces toxicity, mobility or volume of the constituents of concern. At least one alternative will be developed for the category in which engineering controls (e.g., containment) comprise the primary element. In addition, one alternative will be developed for the no action category.

The range of treatment alternatives will be delineated primarily by the degree to which each alternative relies on long-term management of residuals

or untreated waste. One end of the range will be defined by an alternative that utilizes treatment to such a degree that long-term management requirements (including monitoring) are eliminated or reduced to the maximum extent feasible. The other end of this range of treatment options will be defined by an alternative that employs treatment to reduce a principal threat(s) posed by a site, but does not involve treatment of all waste or the highest degree of treatment.

The alternative(s) which relies primarily on engineering controls will typically involve containment of waste, with little or no treatment. A fourth category of alternatives may be developed in which a combination of treatment and containment technologies are implemented to address the goals of the remediation. Purely containment strategies also attempt to meet the remedial objectives for protection of human health and the environment by preventing exposure to the waste contaminants. Containment alternatives are developed and carried through the process to provide a basis for comparison with other alternatives in the treatment, treatment plus containment, and no action categories, and to ensure that such an alternative is available if needed as a remedial component to achieve a protective, practicable, and cost-effective remedy.

The no action alternative will be used as the baseline exposure scenario in the site-specific risk assessment and thus serves as another useful point of comparison with other alternatives.

The preliminary evaluation of remedial actions in this RI report precedes, but will in no way prejudice or limit the more comprehensive review to be performed in the FS. The most promising subset of alternatives developed in the FS will be subject to a preliminary screening step. Effectiveness,

Implementability and cost factors will be evaluated for each alternative as part of this initial screening.

Effectiveness factors relate to the overall performance of alternatives in reducing toxicity, mobility or volume through use of treatment technologies, achieving long-term effectiveness and permanence, and any short-term impacts they may pose. Implementability factors address the degree of difficulty associated with the actual construction of any given alternative, including technical, administrative and logistical problems that primarily affect the time necessary to complete a prospective remedial action. Cost factors include construction costs as well as the cost of operating and maintaining the remedies over time.

A more detailed analysis of the remedial action alternatives which pass the initial screening will include the evaluation of nine criteria, in order to arrive at a recommended remedial action. These nine criteria are:

- Overall protection of human health and the environment,
- Long-term effectiveness and permanence,
- Reduction of toxicity, mobility, or volume,
- Short-term effectiveness,
- Implementability,
- Cost,
- State acceptance,
- Community acceptance, and,
- Compliance with applicable and appropriate or relevant requirements.

The identification of applicable and relevant or appropriate requirements (ARARs), begun in this report, will be completed in the FS during the process of developing suitable remedial response alternatives for each remediated site. The evaluation of potential ARARs will include

chemical-specific ARARs, dependent on the contaminants identified as a concern for remediation; location and site-specific ARARs; and action-specific ARARs pertaining to the response remedy selected at the sites to be remediated. Selected preliminary contaminant and site specific clean-up objectives have been identified in this report. These objectives will be scrutinized further in the FS to assure an outcome which will be protective of wildlife and human health.

SECTION 8 - CONTROL SITES:
SITE 30, THE MUNITION CONTROL SITE AND
SITE 31, THE REFUGE CONTROL SITE

8.1 General

The rationale for selection of the two control sites was discussed in Section 3.5. Site 30, the Munition Control Site, is a control site established for the munitions manufacturing areas. It is located in the south portion of the Refuge, in a low lying area around the bunkers used for munitions storage (See Figure 8-1). According to Refuge personnel, munitions storage is the only industrial activity to have occurred in the area.

Site 31, the Refuge Control Site, is a control area established on the north side of the Refuge, behind the new Refuge Headquarters (See Figure 8-2). According to the Refuge Manager, this area was not involved in any past industrial activities. The Refuge Manager also indicated that a test well was drilled near the headquarters building, tested, and found to be free of contaminants.

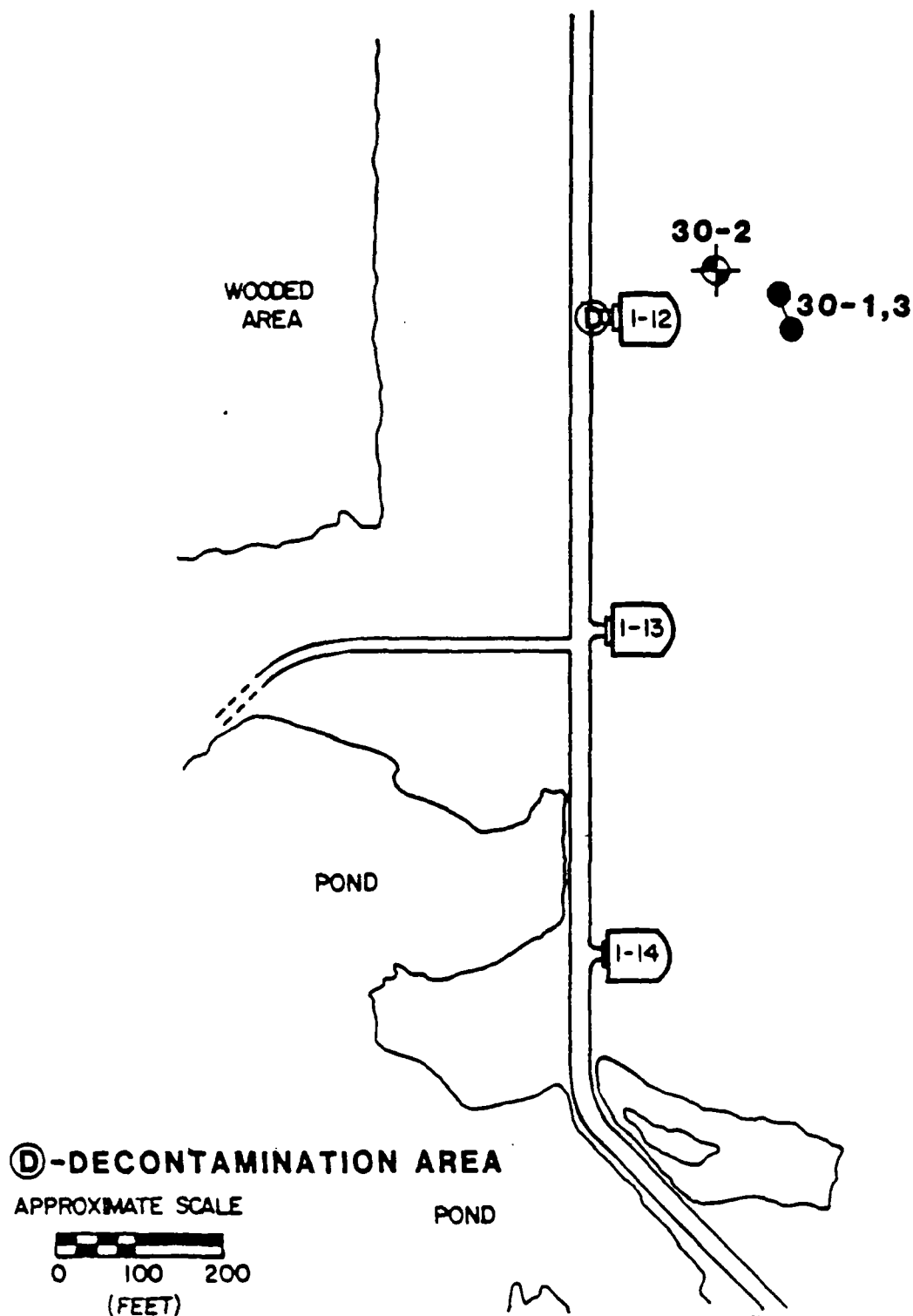
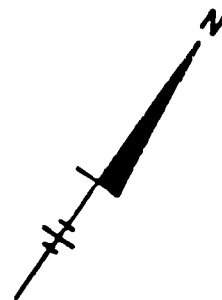
8.2 Site Investigations

8.2.1 Site 30: Munition Control Site

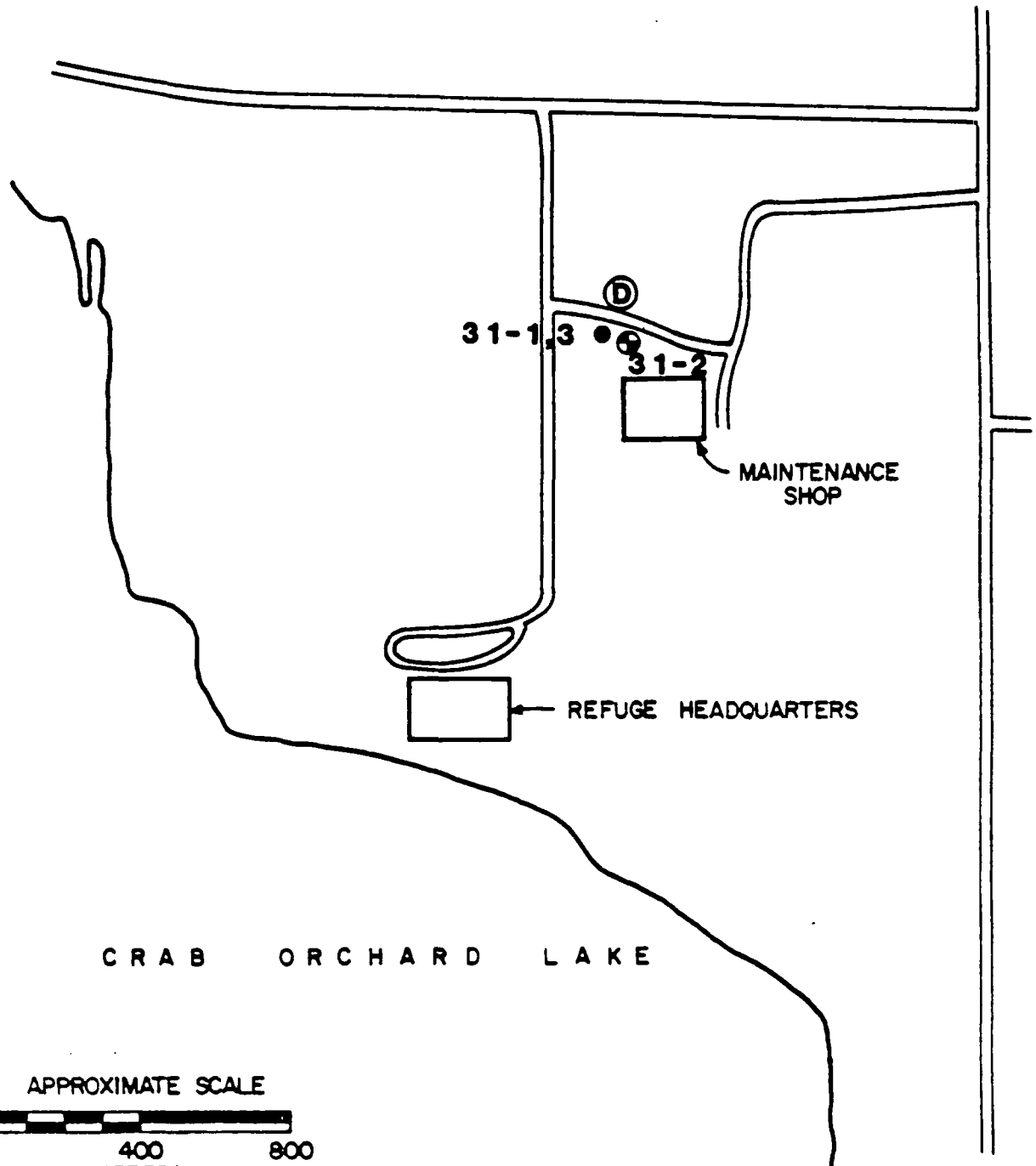
8.2.1.1 Phase I Site Investigations

A monitoring well was installed and one surface soil sample was collected. The well was set at a depth of twenty feet and utilized a ten-foot screen section to monitor the uppermost ground water quality. Subsoils encountered during drilling consisted of predominantly clayey silts.

SITE 30
MUNITIONS CONTROL SITE
PHASES I & II



**SITE 31
REFUGE CONTROL SITE
PHASES I & II**



APPROXIMATE SCALE
0 400 800
(FEET)

Ⓓ - DECONTAMINATION AREA

8.2.1.2 Phase II Site Investigations

The monitoring well and one surface soil were sampled and analyzed. The ground water sample was analyzed for full CLP HSL organics, nitrosamines, PCBs, metals and cyanide. The soil was analyzed for base/neutral/acid extractable compounds and arsenic.

8.2.2 Site 31: Refuge Control Site

8.2.2.1 Phase I Site Investigations

A monitoring well was installed and one surface soil sample was collected. The well was installed to a depth of thirty feet with a ten-foot screened interval. Subsoils encountered during drilling included predominantly clayey silt.

8.2.2.2 Phase II Site Investigations

The monitoring well water and one additional soil sample were collected and analyzed. Full CLP HSL analysis was performed on the ground water sample along with nitrosamines, PCBs, metals, and cyanide analyses. The soil was analyzed for base/neutral/acid extractables and arsenic.

8.2.3 Site Hydrogeologic Characterization

8.2.3.1 Site Geology - Site 30: Munitions Control Site

Based on results of the test boring procedure, the subsurface unconsolidated overburden consists of a mottled grey and brown clayey silt. This material is present from the ground surface to at least 20 ft. in depth as found in Boring 30-2. Bedrock was not encountered in the boring, and therefore it's depth and lithology is unknown. As only one

monitoring well was installed, the lateral extent and variability of the clayey silt is also unknown.

8.2.3.2 Site Hydrogeology - Site 30: Munitions Control Site

Based on the well installation during June 1987, shallow ground water beneath the site was found at a depth of 7 to 12 ft. below the ground surface within the clayey silt soil unit. The monitoring well installed screened this upper water table. Ground water elevations collected during the winter of 1987 and summer of 1987 (wet and dry seasons, respectively) indicate a water table fluctuation of 5 ft. with water levels dropping during the summer months (Table 4-3). Figure 8-3 illustrates the monitoring well location and the ground water elevation as of 18 June, 1987.

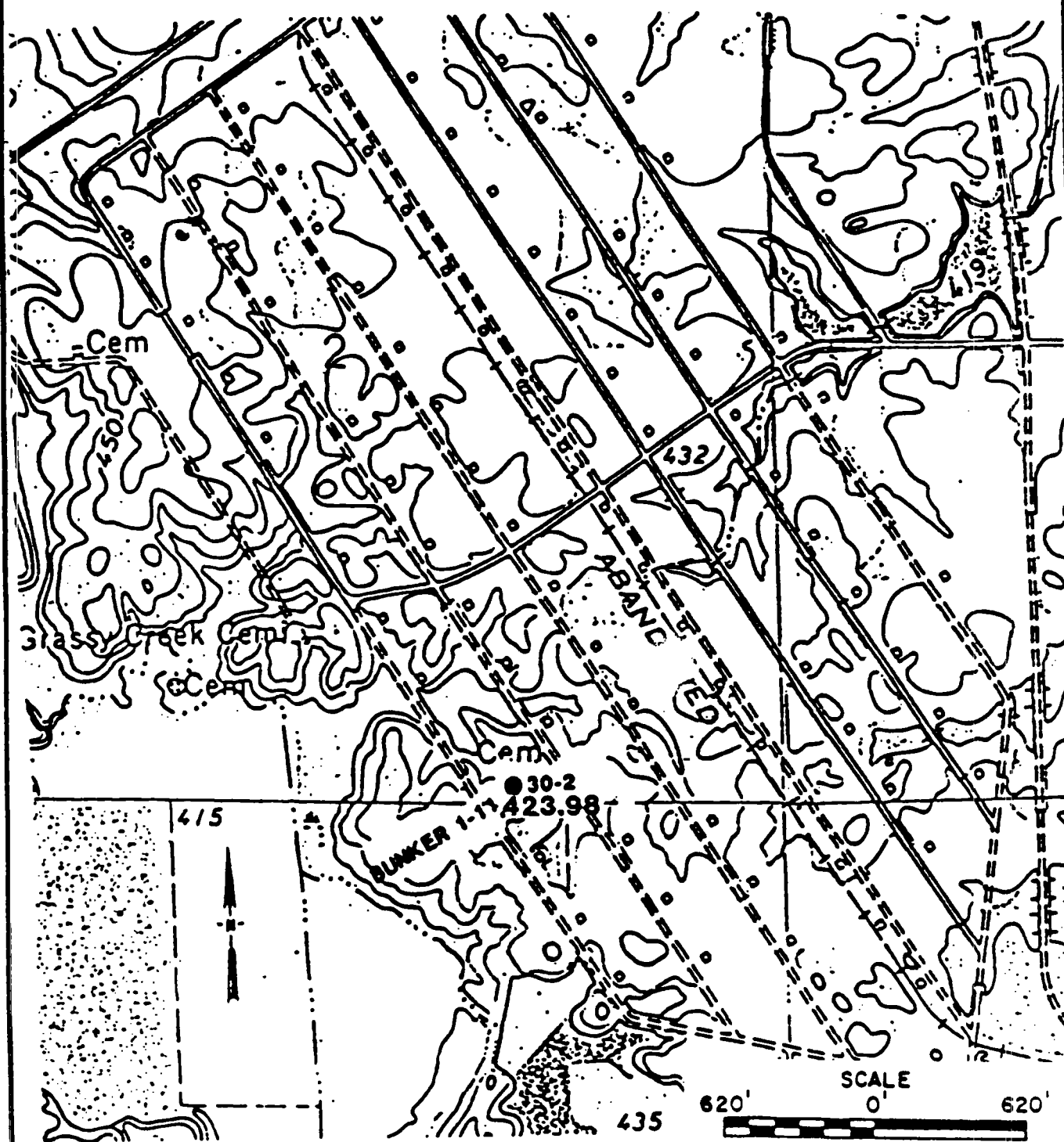
8.2.3.3 Site Geology - Site 31: Refuge Control

Based on results of the test boring procedure, the subsurface unconsolidated overburden consists of a medium to dark brown clayey silt. This material is present from the ground surface to at least 30 ft. in depth, as was found in Boring 31-2. Bedrock was not encountered in the boring, and therefore depth to bedrock and bedrock lithology is unknown. As only one monitoring well was installed, the lateral extent and variability of the clayey silt is also unknown.

8.2.3.4 Site Hydrogeology - Site 31: Refuge Control Site

Based on the well installation, shallow ground water occurring beneath the site was found at a depth of 12 to 14 ft. below the ground surface within the clayey silt soil unit. The monitoring well installed

SITE 30 WELL & GROUNDWATER ELEVATION MAP



SITE 30 - MUNITIONS CONTROL SITE

30-2

JUNE 18, 1987

● - MONITORING WELL LOCATION &
IDENTIFICATION

423.98 - GROUND WATER ELEVATION

screened this upper water table. Ground water elevations collected during the winter and summer of 1987 (wet and dry seasons, respectively) indicate a water table fluctuation of 2 ft. with water levels dropping during the summer months (Table 4-3). Figure 35-5 illustrates the monitoring well location and the ground water elevation as of 18 June, 1987.

8.3 Analytical Results (Appendix I, Page 20)

8.3.1 Site 30: Munition Control Site

8.3.1.1 Phase I Analytical Results

The volatile and semi-volatile organics data for Phase I are questionable due to QA/QC deficiencies or unreliable support data (see Exhibit B). The positive detections reported are thus estimated values and some compounds which were not detected may in fact be present.

Di-n-octyl phthalate was reported in the soil at a concentration of 83,900 ug/kg (wet weight); all other organics were below the detection limits or were also detected in the QA/QC blank samples. Arsenic (20 mg/kg, less than 7 mg/kg duplicate), magnesium (1320 mg/kg and 1380 mg/kg) and zinc (400 mg/kg and 43 mg/kg) were detected; however, these values are estimated for screening purposes only. All other concentrations were within the ranges commonly found in soil matrices (Lindsay, 1979).

8.3.1.2 Phase II Analytical Results

The groundwater contained detectable levels of arsenic (5 total/less than 2.7 filtered ug/L), chromium, (17 total/below 1 filtered ug/L) and lead (9.3 total/below 1.3 filtered ug/L). None of these concentrations

exceed Illinois Public Water Supply Standards or drinking water MCLs or proposed MCLGs. Isophorone and acetone were detected (204 and 12 ug/L) in the groundwater sample, as well as in the QA/QC sample; they are thus likely a result of laboratory or sampling contamination. The soil sample contained 12 mg/kg arsenic. Di-n-octyl phthalate was not detected in the Phase II soil analysis, but di-n-butyl phthalate was detected at 400 ug/kg. All other concentrations were within the ranges commonly found in soil matrices (Lindsay, 1979).

8.3.2 Site 31: Refuge Control Site (Appendix I, page 33)

8.3.2.1 Phase I Analytical Results

Traces of acetone (216 ug/kg) and methylene chloride (546 ug/kg) were detected in the surface soils. These organics were also detected in the QA/QC samples and therefore may be present as a result of laboratory or sample handling. All other concentrations were within the ranges commonly found in soil matrices (Lindsay, 1979).

8.3.2.2 Phase II Analytical Results

Trace levels of organics detected in the groundwater included methylene chloride (6 ug/L), 1,1,1-trichloroethane (18 ug/L), and acetone (14 ug/L). Acetone and methylene chloride were also detected in blank samples, possibly as a result of laboratory or sample handling. Chromium and arsenic were detected at 2.1-24 ug/L and 3.6-16 ug/L respectively. None of these concentrations exceed Illinois Public Water Supply Standards or drinking water MCLs or proposed MCLGs. The soil sample contained traces of arsenic (13 mg/kg) in addition to 200 ug/kg bis (2-ethyhexyl) phthalate and 340 ug/kg di-n-butylphthalate. All

other concentrations were within the ranges commonly found in soil matrices (Lindsay, 1979).

8.4 Refuge Background Levels

Table 8-1 summarizes the concentrations in soils for all compounds analyzed at the control sites. The concentrations in soils at other study sites have been discussed in reference to the levels detected at the control sites. In general, non-carcinogenic inorganic parameters were eliminated from concern if they were detected at concentrations within an order of magnitude of background levels detected at the control sites.

Background levels for arsenic and magnesium in Refuge soils are slightly higher than is typical for soils in this part of the country. Ranges of 10-80 mg/Kg arsenic and 1000 - 10,000 mg/Kg magnesium in soil matrices from the Refuge can partly be attributed to previous land use activities including explosives manufacturing, coal mining, and widespread spraying with lead arsenate for pesticide control.

Background levels for organic parameters range from low parts per billion levels to undetectable. Organic parameters, when detected above the levels detected for the control sites, are discussed in the subsection titled "Environmental Effects" for each site.

All concentrations in ground water and lake samples were compared to applicable Federal and State regulatory standards, including the National Interim Primary and Secondary Drinking Water Standards, Illinois Public Water Supply Standards, and Illinois General Use Water Quality Standards. Lake samples and those detected parameters for which no standards exist were also compared to the Ambient Water Quality Criteria (AWQC) for protection of human health (10^{-6} risk level) and freshwater aquatic life.

REFUGE CONTROL SITES & BACKGROUND FOR SOILS

- Compounds Above the Detection Limit -

Note: See key to qualifiers
at end of Table.

UNITS	31-1-1-4	31-1-1-7	131-3-1-18	140-75-1-181	30-1-1-4	140-49-1-4	30-1-1-7	130-3-1-18
	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
	19206 LN	9284 LN	1131550 LN	67461 LN	9461 LN	19289 LN	9274 LN	66658 LN
	8/14/85	11/19/85	12/11/86	12/11/86	8/16/85	8/16/85	11/19/85	12/13/86

(Concentrations based on dry weight)

VOLATILES/SEMI-VOLATILES

13 Acetone	ug/kg		1708W				1708W	11.6J
14 Benzene	ug/kg	(12	(5W		(14	(15	27W	
29 Methylene Chloride	ug/kg	(12	4298W		(14	(15	2008W	
37 Tetrachloroethene	ug/kg	(12	(5W		(14	(15	31W	
230 FID Scan	ug/kg	3190			(140	661		
91 Di-n-butyl phthalate	ug/kg		(330W	340J	455		5JW	400J
92 Di-n-octylphthalate	ug/kg		484W	(410	(410		83900W	(410
95 Diethylphthalate	ug/kg		20JW	(410	(410		(330W	(410
106 N-Nitrosodimethylamine	ug/kg		(330W	(410	(410		94JW	(410

METALS

156 Aluminum	mg/kg	10700			11400	13300		
158 Antimony	mg/kg	8.2			6.5	6		
160 Arsenic	mg/kg	7			20	7		12SR
162 Barium	mg/kg	124			106	102		
164 Beryllium	mg/kg	BDL			0.2	BDL		
168 Calcium	mg/kg	630			1470	1710		
170 Chromium	mg/kg	14			14	14		
172 Cobalt	mg/kg	10			6	6		
174 Copper	mg/kg	7.7			11	9.6		
176 Iron	mg/kg	11400			12800	13100		
178 Lead	mg/kg	22			19	14		
180 Magnesium	mg/kg	1210			1320	1380		
182 Manganese	mg/kg	1730			626	606		
152 Molybdenum	mg/kg	2			2	2		
186 Nickel	mg/kg	10			9	10		
190 Selenium	mg/kg	(20			BDL	(20		
194 Sodium	mg/kg	60	140		50	60	140W	
196 Tin	mg/kg	BDL			BDL	BDL		
198 Thallium	mg/kg							
154 Titanium	mg/kg	278			143	239		
200 Vanadium	mg/kg	26			29	29		
202	mg/kg	36			400	43		

REFUGE CONTROL SITES & BACKGROUND FOR SOILS

- Compounds Above the Detection Limit -

Note: See key to qualifiers
at end of Table.

PARAMETERS

UN116	31-1-1-4	31-1-1-7	131-3-1-18	140-75-1-181	30-1-1-4	140-49-1-4	30-1-1-7	130-3-1-18
	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
	19206 LN	9284 LN	1131550 LN	67461 LN	9461 LN	19289 LN	9274 LN	66658 LN
	8/14/85	11/19/85	12/11/86	12/11/86	8/16/85	8/16/85	11/19/85	12/13/86

(Concentrations based on dry weight)

INDICATORS

213 Ammonia Nitrogen	mg/kg	38			118	114	
214 Cation Exchange Capacity	meq/100 g		15.3				15.2M
217 Nitrate Nitrogen	mg/kg	7			13	43	
218 Nitrite Nitrogen	mg/kg	4			21	37	
232 Organic Nitrogen	mg/kg	490			149	470	
219 pH	s. u.	7.4			7.7		
220 Percent Total Solids	%	81.51	78.53		71.24	65.08	
221 Specific Conductivity	umhos/cm	475			967	1169	
240 Total Carbon	mg/kg	6134			6176	6146	
222 Total Inorganic Carbon	mg/kg	736			1140	1154	
223 Total Kjeldahl Nitrogen	mg/kg	528			267	584	
224 Total Organic Carbon	mg/kg	5398			6036	5993	
225 Total Organic Halides-1	ug/kg	12.00			BDL	3.7	
244 Total Organic Halides-2	ug/kg	11			34	80	
226 Total Phosphorus	mg/kg	156			216	175	

KEY

B= Level reported is (10X the level detected in QA/QC blank.

BDL= Below Detection Level.

J= Concentration quantified is below the detection level.

R= Spike sample recovery is not within control limits.

S= Value is determined by method of Standard Addition.

W= Value reported as wet weight.

SECTION 9 - SITE 3, AREA 11 SOUTH FIELD

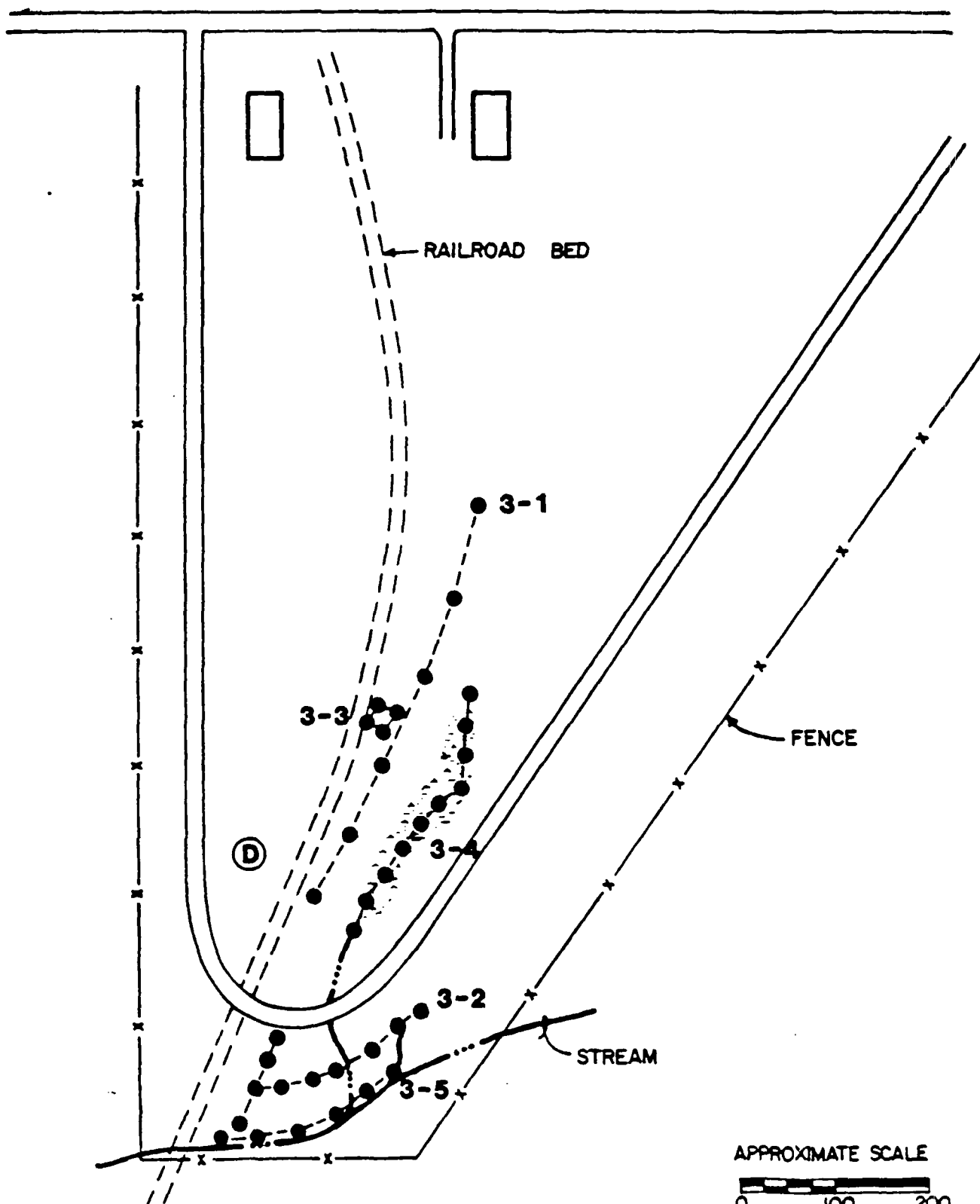
9.1 Site Description

Area 11 is an abandoned site which was at one time used for explosives and nitrogen fertilizer manufacturing as well as munitions loading. The Olin Corporation is reported to have operated a dynamite line there which was later sold to U.S. Powder. A number of fires and explosions are known to have occurred in these areas. The Refuge Manager has indicated that lead azide (an explosive component) and RDX may have been used in this area. Many of the buildings and grounds were "torched" to remove residuals of flammable material. Most of the buildings are covered with a spark-retarding asbestos siding material.

Explosive powders were stored in rubber-lined underground trenches in several storage areas within Area 11. A burning pad is located south of Area 11 where oil residues, 53-calibre powder magazines and small powder cylinders are noticeable on the surface. The trenches and the burning pad were not included in this scope of work, since they were to be evaluated by the DOD.

Site 3 is an area located adjacent to an old railroad spur that served abandoned explosive manufacturing areas (See Figure 9-1). Surface litter is evident over an area of approximately ten acres. The observable debris consists of railroad tracks, ties and ballast, cinders, charred wood, powder canisters, piping, metal, mesh, bricks, pumice blocks, 30- and 55-gallon steel drums, reinforcing bars, a laboratory flask and miscellaneous wire and plastic articles. One mound on the bank just above the stream bed has several of what appeared to be metal vents on the top and a 4-inch stainless steel pipe drain extending from the bottom. The stream bed west of the road appeared to

SITE 3
AREA II SOUTH FIELD
PHASE 1



(D) - DECONTAMINATION AREA

APPROXIMATE SCALE
0 100 200
(FEET)

contain especially heavy concentrations of debris. Black tars and ash were evident in the stream bed.

9.2 Site Investigations

9.2.1 Phase I Site Investigations

Three composite soil samples (0-1 ft depth) were prepared from grab surface soils collected along the north, south and east banks. Two sediment composites (0-1 ft depth) were collected, one from the marsh and one from the lower stream.

9.2.2 Phase II Site Investigations

No Phase II activities were performed, as the Refuge Manager indicated that the DOD will be responsible for further action.

9.3 Analytical Results (see Appendix I, page 1)

Trace amounts of explosive residues HMX (up to 2.6 mg/kg) and RDX (up to 6.4 mg/kg) were detected in the soil and sediment. Lead concentrations of 415 and 510 mg/kg were detected in the soils and sediments, and zinc concentrations up to 1380 mg/kg were detected in the sediment. Metals concentrations are reported as estimated values for screening purposes (see Exhibit B). Soil Sample 3-2 contained 16,885 ug/kg organics by FID screening and was therefore selected for full CLP organics testing. The volatile and semi-volatile organics data for Phase I are questionable due to QA/QC deficiencies or unreliable support data (see Exhibit B).

The positive detections reported are thus estimated values and some compounds which were not detected may in fact be present. The soil possibly contained 3580 ug/kg wet weight n-nitrosodiphenylamine, and 389 ug/kg wet

weight of 2,6-dinitrotoluene. Small quantities (24 to 184 ug/kg wet weight) of tetrachloroethene were found in one soil and two sediment samples. Four of the five samples contained traces of PCBs (less than 1 mg/kg wet weight).

9.4 Environmental Effects

The Refuge Manager has indicated that the DOD will be responsible for further action at this site.

The analytical survey of Site 3 detected several organic and inorganic contaminants in soil and sediment, including nitroso diphenyl and dimethyl amines. The areas sampled were collected mostly from drainage areas to conduct a general survey of the site for screening purposes, usable for qualitative characterization but not to support a quantitative risk assessment. In addition, various deficiencies in the Phase I data analyses were noted. For this reason, additional site investigations will be required prior to assessing the risks associated with this site.

9.5 Preliminary Remedial Alternatives

The DOD will be responsible for further action at this site.

9.6 Conclusions and Recommendations

The Refuge Manager has indicated that the DOD will be responsible for further action at this site.

SECTION 10 - SITE 4, AREA 11 NORTH FIELD

10.1 Site Description

Information on Area 11 can be found in Section 9.1. The Area 11 North Field appears to have been the site of a two to three acre impoundment (See Figure 10-1). The impoundment is flat and dry in the middle and has small intermittent streams or marsh areas bordering the east and west boundaries. Water appears to flow from south to north following periods of precipitation. The remains of a reinforced concrete dam can be seen at the northwest end of the site. An earthen bunker is located immediately to the west. It may have been built with earth excavated from the semi-marshy lagoon area and may have been constructed to protect the explosives processing areas located further to the west.

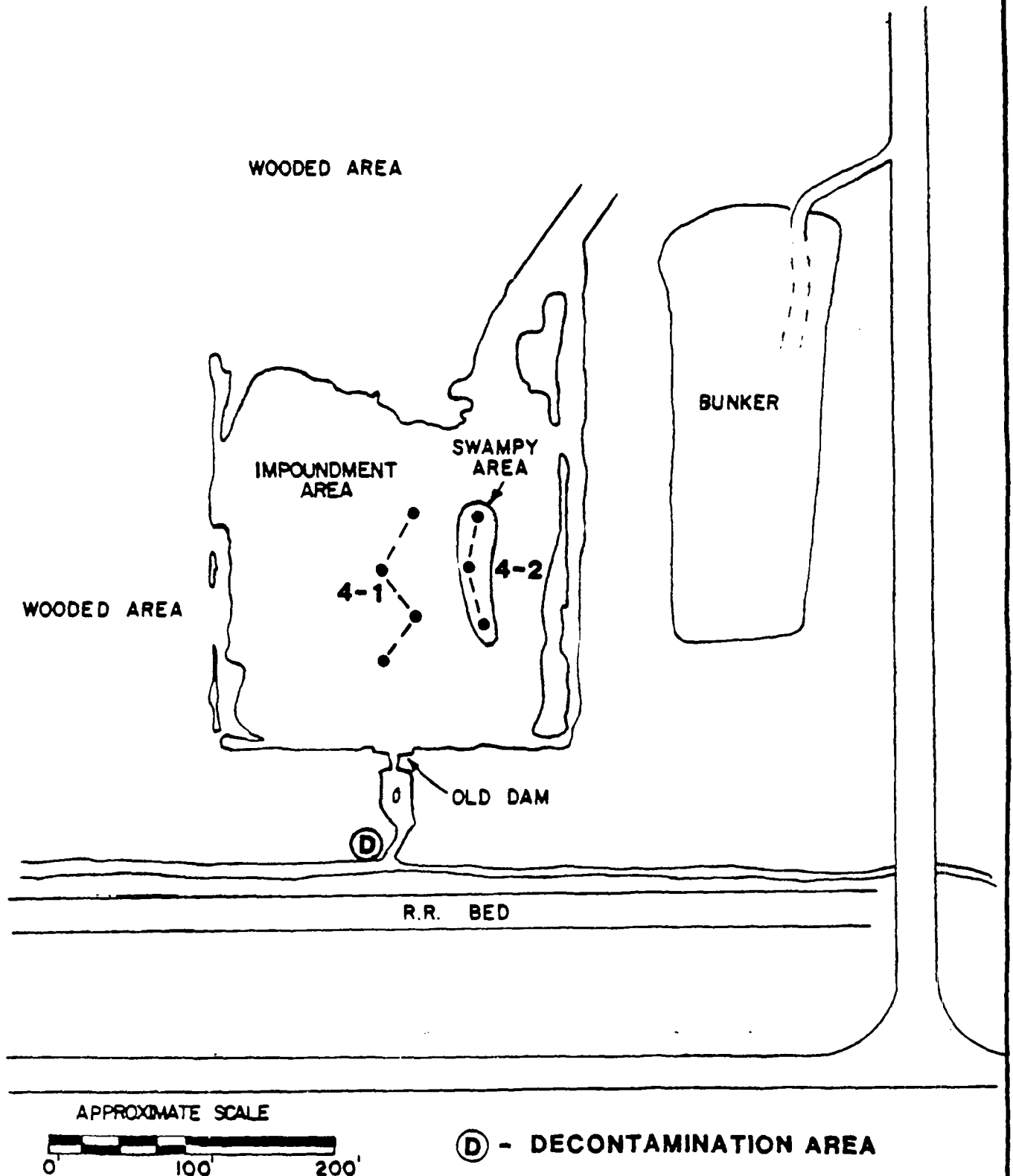
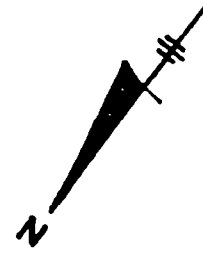
The Refuge Manager has speculated that RDX or magnesium may have been stored underwater, or the site may have been used to detonate explosives or for experimental detonations. The level bottom of the impoundment contains areas of grassy vegetation but shows a number of bare patches of fine white silt or clay. Other weathered areas show horizontal layering of white and gray sediments. A number of dynamite-type fuses were noticed here as well as a small powder carrier, 1.5-inch diameter by 3-inch length, with the fuse intact. Small chunks of lead metal were also observed.

10.2 Site Investigations

10.2.1 Phase I Site Investigations

One surface soil composite (0-1 ft depth) and one surface sediment composite (0-1 ft depth) were collected. (See Figure 10-1). The sediment composite was resampled for full organics screening.

SITE NO. 4
AREA 11 NORTH FIELD
PHASE 1



10.2.2 Phase II Site Investigations

No Phase II activities were performed, as the Refuge Manager indicated that the DOD will be responsible for further work at this site.

10.3 Analytical Results (See Appendix I, page 2)

A trace (1.5 mg/kg) of the explosive 2,4-dinitrotoluene was found in the soil. The sediment sample had an FID screen of 1341 ug/kg and was then resampled for full CLP organics analysis. Among the organics, only n-nitrosodimethylamine (1055 ug/kg wet weight) was above 1 mg/kg. However, the volatile and semi-volatile organics data for Phase I are questionable due to QA/QC deficiencies or unreliable support data (see Exhibit B). The positive detections reported are thus estimated values and some compounds which were not detected may in fact be present. With the exception of sodium (780-5910 mg/kg), all heavy metal concentrations were similar to those in soils at the control sites. The soil contained among the highest specific conductance (22,800 umhos/cm) and nitrate (2286 mg/kg) of the 328 Phase I soil samples collected at the Refuge. This may indicate the presence of degradation products from explosives components.

10.4 Environmental Effects

The Refuge Manager has indicated that the DOD will be responsible for further action at this site.

The samples at Site 4 were collected mainly from drainage areas to conduct a general survey of the area for screening purposes, usable for qualitative characterization but not to support a quantitative risk assessment. Various deficiencies were reported in the Phase I analytical data. Therefore, the detection of inorganic and organic species, including

N-nitrosodimethylamine, are qualitatively estimated. The significance of nitrosodimethylamine residues is discussed in detail in Section 23.4 (Site 19); based on the evaluation of similar contaminant levels at that site, it was determined that nitrosoamines do not present any significant risks to humans. Exposure to nitrosoamines residues in sediment by wildlife is limited due to the swampy nature of this area, and the absence of fish or other potential aquatic receptors, such that the exposure pathway is incomplete for wildlife.

Due to the limited database, the screening nature of the sampling survey for this site, and the results of the evaluations for similar levels of contaminants at other sites, a quantitative risk assessment was not developed for this site. Additional site investigations are required in order to determine the extent of contamination at this site.

10.5 Remedial Alternatives Evaluation

The DOD will be responsible for further action at this site.

10.6 Conclusions and Recommendations

The Refuge Manager has indicated that the DOD will be responsible for further action at this site.

SECTION 11 - SITE 5, AREA 11 ACID POND

11.1 Site Description

Further Information on Area 11 can be found in Section 9.1. The Area 11 Acid Pond is a diked impoundment approximately 300 ft x 150 ft which received drainage flowing north from the Area 11 process buildings (See Figure 11-1). The dike extends five to six feet above the current water level. A 12-inch diameter pipe exits to the west through the levee to a valve box which controls the discharge from the pond to a small stream. The drainage then exits through the woods and swampy areas to the north. The Refuge Manager indicated that years ago an accidental discharge of acidic water, possibly containing nitric acid, from the pond killed all of the downstream vegetation for 1/4 mile. A large stand of dead trees is visible along the creek northwest of the pond. Frogs and fish were observed in the pond.

11.2 Site Investigations

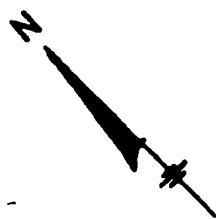
11.2.1 Phase I Site Investigations

One composite sample each of surface water, and sediment (0-1 ft depth) were collected from the pond. The sediment was sampled for full organics analysis. In addition, one composite soil sample (0-1 ft depth) was collected downstream from the pond adjacent to the dead trees (See Figure 11-1).

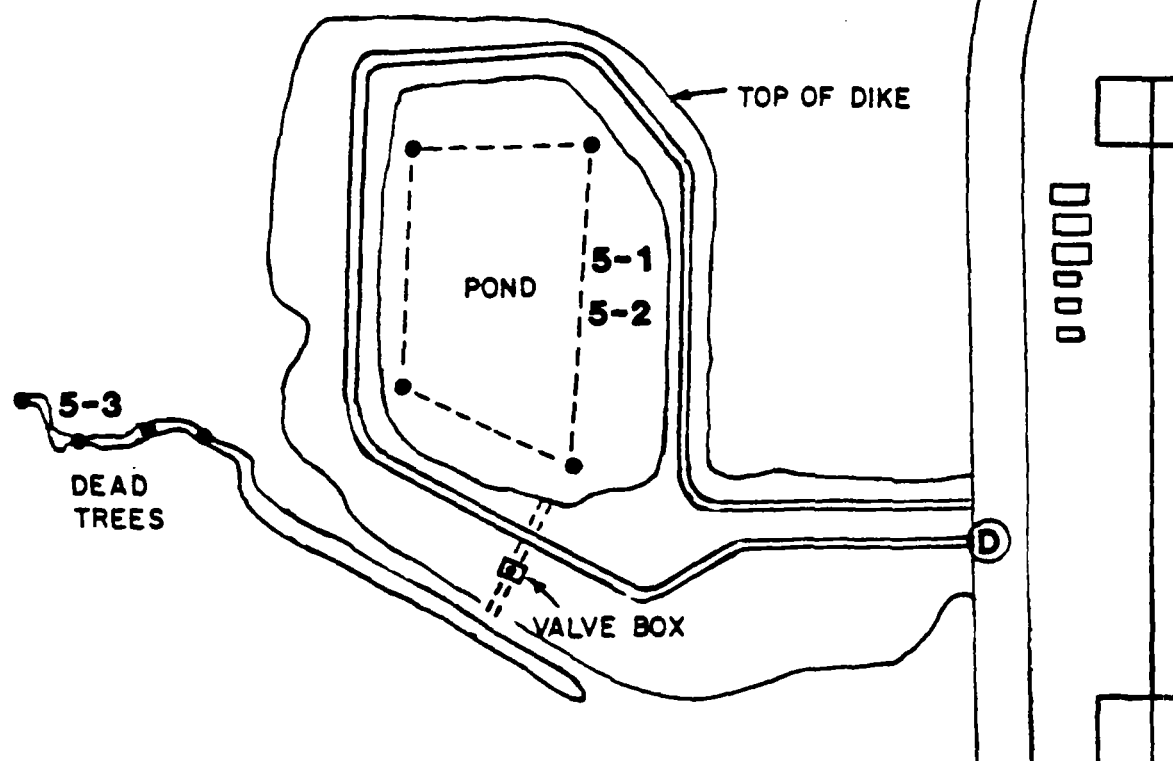
11.2.2 Phase II Site Investigations

No Phase II sampling was conducted since the analytical results from the Phase I screening did not indicate that any parameters were present at levels of concern.

SITE NO. 5
AREA II ACID POND
PHASE I

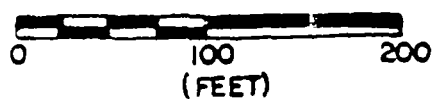


WOODED AREA



Ⓓ - DECONTAMINATION AREA

APPROXIMATE SCALE



11.3 Analytical Results (Appendix 1, page 3)

Values for pH were 7.3 for water, 5.7 for sediment, and 7.1 for soil. These values indicate that acid residuals have been neutralized or dissipated. Chromium residuals (140 and 110 mg/kg) were detected in the soil and sediment, but not in the water. The chromium values are estimated and are reported for screening purposes only. The sediment sample contained 1035 ug/kg wet weight N-nitrosodimethylamine, and 10,300 ug/kg wet weight di-n-octyl phthalate. All other organics were below the detection limits. The volatile and semi-volatile organics data for Phase I are questionable due to QA/QC deficiencies or unreliable support data (see Exhibit B). The positive detections reported are thus estimated values and some compounds which were not detected may in fact be present.

Specific conductance of the pond water was fairly high (37,600 micromhos/cm), and iron (500 ug/L) and manganese (100 ug/L) were above their respective MCL standards. These excursions do not represent a threat to public health or the environment since the standards for manganese and iron are based on aesthetic concerns of taste and color. No other components were detected at levels above Illinois Public Water Supply standards or Federal Drinking Water MCLs.

11.4 Environmental Effects

11.4.1 Qualitative Assessment

This site was chosen for investigation based on verbal accounts that an acidic chemical spill had occurred many years ago, possibly contaminating the pond, the exit stream of the pond and the immediate surrounding areas. However, based on the Phase I sampling data results

for water, sediment and soil, the site did not indicate an impact from an acidic release.

Traces of chromium and N-nitrosodimethylamine were detected in sediments at levels approximately one order of magnitude higher than the concentrations found at the Refuge control sites. Analyses of the pond water did not show detectable levels of chromium and the screenings for base/neutral and acid extractable compounds were below the detection limit of 100 ug/L. Chromium levels in soil and sediments are well within the ranges typical for soil matrices (Lindsay, 1979). N-nitrosodimethylamine was detected at higher levels at Site 19 (Section 26.4) where it was not considered to pose unacceptable risk levels to humans based on the quantitative assessment prepared for that site. N-nitrosodimethylamine could potentially pose a risk to bottom-dwelling aquatic species via exposure to pond bottom sediments; however, there is insufficient information on the distribution of contaminants in pond sediments, or on the effects from low sediment-bound residues to potentially exposed aquatic biota such as amphibian and benthic organisms existing in this pond.

Di-n-octylphthalate was also detected but at comparable concentrations to the levels found at the control sites. The detection of phthalate esters may be related to their presence as a common laboratory contaminant.

11.4.2 Quantitative Assessment

Because a complete exposure scenario could not be identified in the qualitative assessment, there is no basis for preparing a quantitative risk evaluation.

11.4.3 Analysis of Uncertainties

The major pieces of Information relied upon for evaluating this location were the verbal accounts of activities on the site, site inspection and sample analyses, all of which suggested the area could have had wastes on it at one time. An inspection of the site revealed that a large number of trees lining the discharge creek were dry.

Chemical residue information was obtained only for the top one foot of soil; deeper soil borings and ground water monitoring were not conducted. Since contamination of the site occurred through accidental discharge of an acidic solution into the pond, the area of soil contamination is likely to be limited to the surface.

Since there is no evidence to suggest that the surrounding soil has been disturbed, these samples should adequately represent the conditions of the site.

Traces of N-nitrosodimethylamine, chromium and di-n-octyl phthalate were found in sediments near the pond, but were not detected in the water. The levels detected were not considered to represent a concern based on the concentrations of similar contaminant levels evaluated for other sites, and the values which are typical for soil matrices. Based on the data, it appears that any acidity, if previously present, has been naturally mitigated. The only parameter found in the soil sample downstream was chromium.

It can be concluded that the data generated are adequate for the evaluation of this site. The pH values verify that the acid from the spill has been neutralized. Contaminants in the surrounding soil are not present at levels that would present a threat to human health or the environment.

11.5 Remedial Alternatives Evaluation

Preliminary Phase I screening results discussed in the previous section indicated that this site does not contain contaminant levels that would result in a negative environmental impact. Therefore, this site was not included in the Phase II investigations. There will be no further evaluation of remedial alternatives, and this site will not be included in the FS.

11.6 Conclusions and Recommendations

It can be concluded that the Acid Pond site does not represent a chemical exposure risk to human or wildlife receptors at the Refuge or at other locations. No further evaluation is recommended for this site.

SECTION 12 - SITE 7, D AREA SOUTHEAST DRAINAGE CHANNEL

12.1 Site Description

Area D is an active Olin operation located north of Crab Orchard Lake. This area is currently used for the manufacture of explosives. The site was previously used by Universal Match under contract to the DOD. Their operations ceased after a large fire, according to the Refuge Manager.

Site 7 is a location within one of the drainage channels leading from the Olin D Area (See Figure 12-1). These channels discharge to Crab Orchard Lake near the Refuge Waterworks.

12.2 Site Investigations

12.2.1 Phase I Site Investigations

One composite surface water sample and one composite sediment sample (0-1 ft depth) were collected.

12.2.2 Phase II Site Investigations

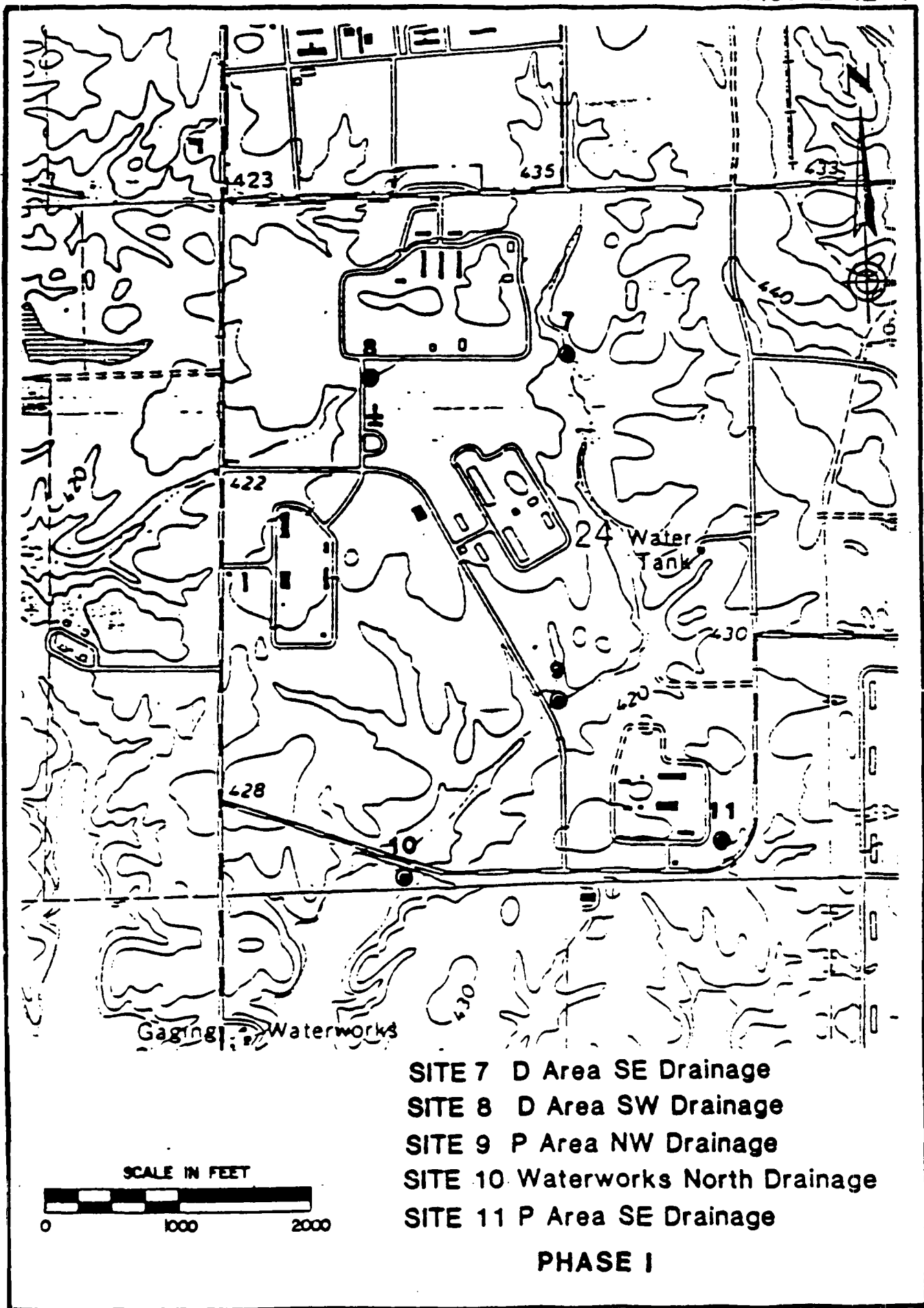
One Phase I sediment sample was reanalyzed for mercury during Phase II.

12.3 Analytical Results (see Appendix I, page 6)

12.3.1 Phase I Analytical Results

The surface water sample contained TOX levels on the order of 43 ug/L, but volatile organics were not detected. Manganese and iron in the water sample (1.5 and 3.2 mg/L respectively) exceeded the Federal MCLs and the Illinois water standards. However, levels of iron and manganese above these aesthetic-based standards do not represent a cause for

FIGURE 12-1



concern nor pose any risk to human health or wildlife. With the exception of magnesium (4480 - 16700 mg/kg), all concentrations in sediments were similar to soil concentrations at the control sites. However, these concentrations are estimated and are included for screening purposes (see Exhibit B); some compounds which were not detected may in fact be present. The sediment contained 6 ug/kg of mercury, 10 ug/kg in the duplicate, but mercury analyses were repeated in Phase II due to questionable calibration data.

12.3.2 Phase II Analytical Results

The mercury concentration in the sediment sample was 40 ug/kg (300 ug/kg duplicate).

12.4 Environmental Effects

Environmental effects of drainage within the D and P areas are discussed in Section 16.4.

12.5 Preliminary Remedial Alternatives

Preliminary Remedial Alternatives for the D and P areas are discussed in Section 16.5.

12.6 Conclusions and Recommendations

Conclusions and Recommendations for the D and P areas are discussed in Section 16.6.

SECTION 13 - SITE 7A, D AREA NORTH LAWN

13.1 Site Description

Area D is an active Olin operation located north of Crab Orchard Lake. Section 12.1 contains a description of previous activities at Area D.

Site 7A is a 3-acre lawn located northwest of the Olin D Area Complex (see Figure 13-1). It was reported that barrels of chemicals were dumped on a knoll within the lawn. No evidence of a knoll remains, but there are a number of depressions with brown patches. A visually clean drainage channel is located south of the lawn and exits under a fence to the west. Other moist drainage areas extend to the wooded area to the west of the site.

13.2 Site Investigations

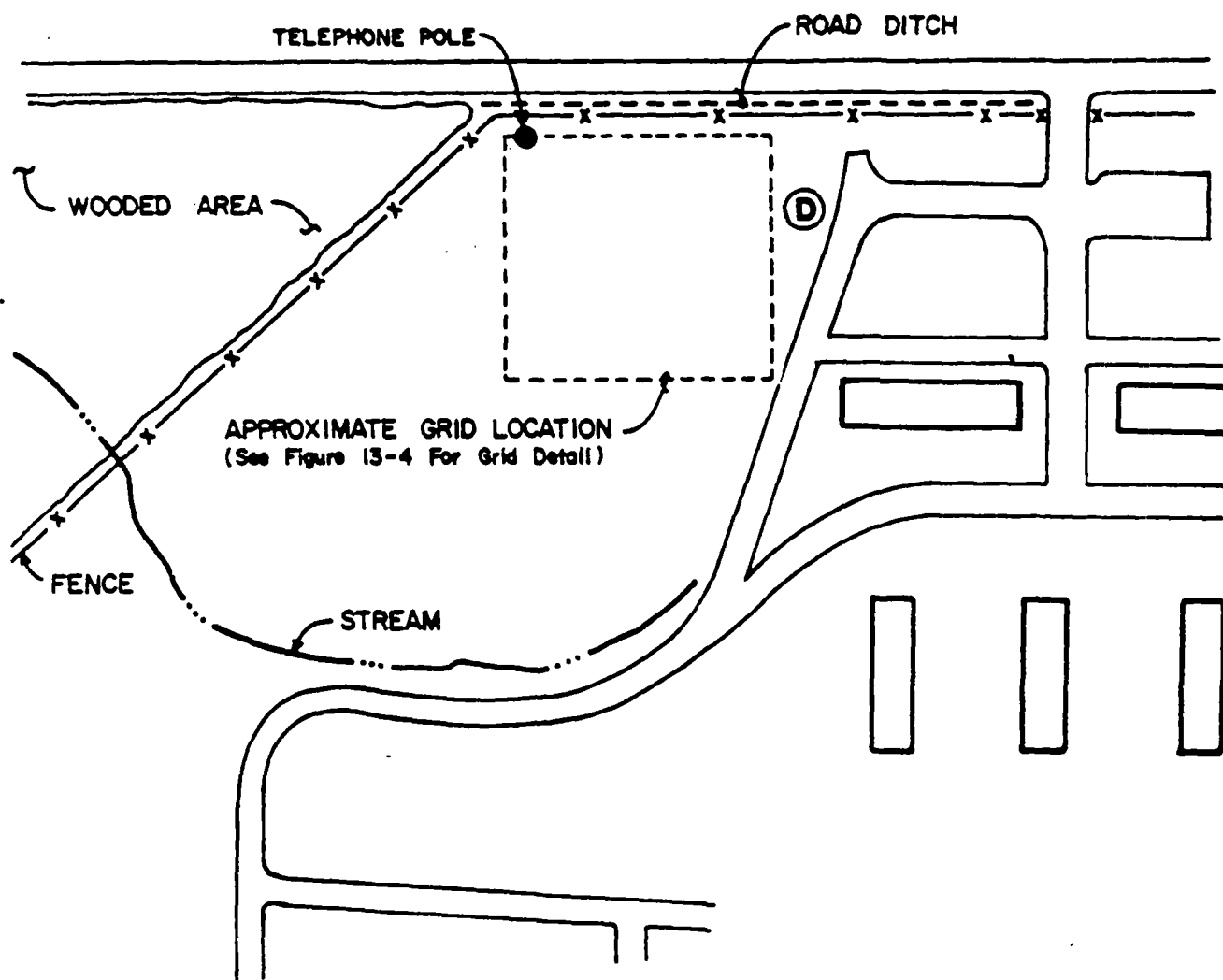
13.2.1 Phase I Site Investigations:

A magnetometer and electromagnetic terrain conductivity survey was performed over the 300 ft x 200 ft lawn on 20 ft x 20 ft grid spacings. The results of these surveys are shown on Figures 13-2 and 13-3. The magnetic anomalies to the north of the sampling area are attributed to power lines. No other anomalies suggestive of buried metallic objects were observed.

Three transects were established and composite soil samples were collected along these transects at the surface as well at depth intervals of 6-12 in., 1-2 ft, and 2-3 ft. Composite soil samples were also collected at the same depths of a low spot in the lawn. One surface soil from Transect B was resampled for full priority pollutant analysis. These locations are shown on Figure 13-4.

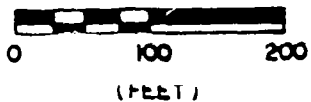
**SITE NO. 7A
D AREA NORTH LAWN
PHASE I**

STUDY AREA LOCATION

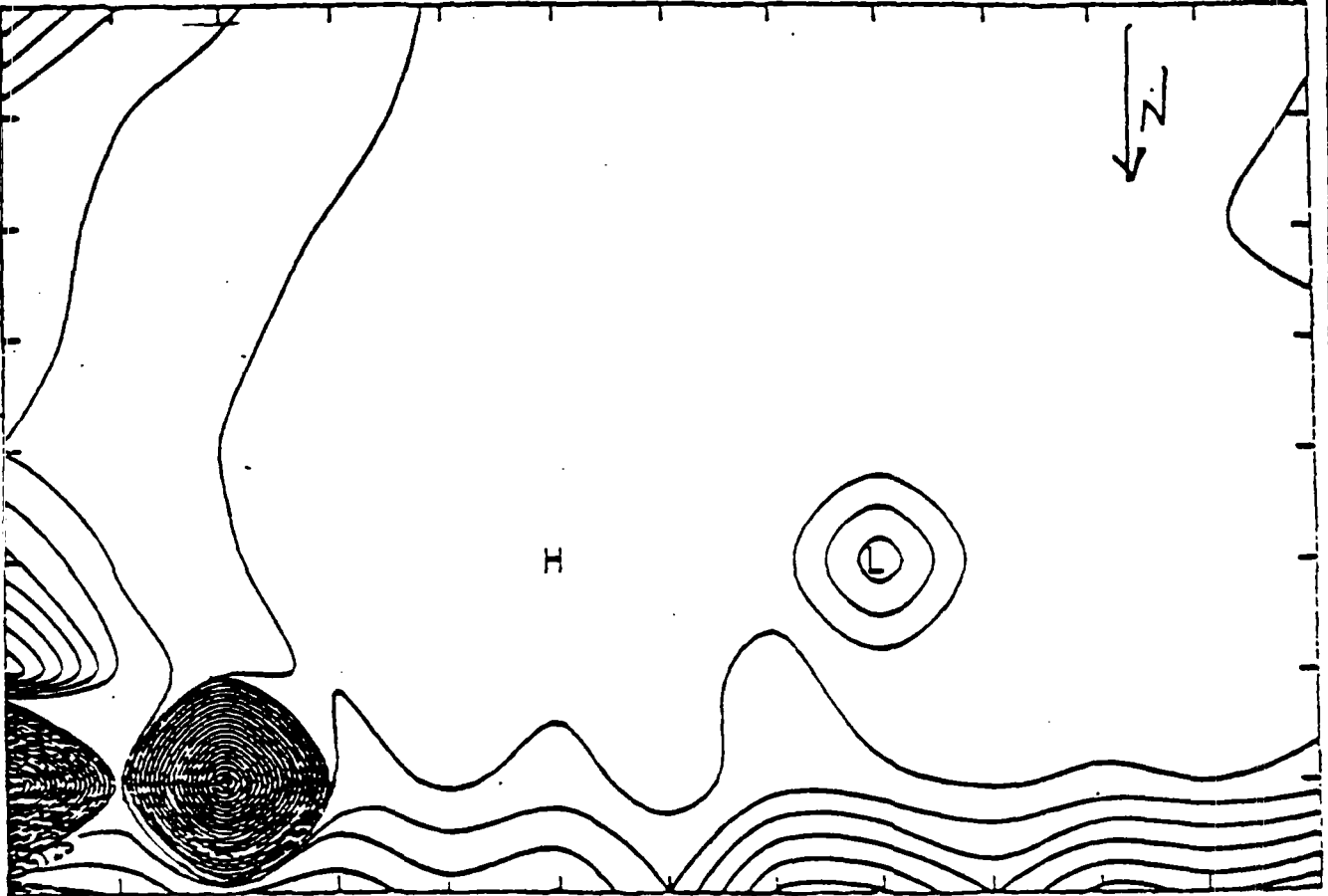


① - DECONTAMINATION AREA

APPROXIMATE SCALE



SITE 7A
MAGNETOMETER SURVEY



CONTOUR FROM 54825. TO 56325. CONTOUR INTERVAL OF 50.000 PT (3.31) = 55267.

SITE 7A ELECTROMAGNETIC SURVEY



CONTOUR FROM 41.000 TO 81.000 CONTOUR INTERVAL OF 5.0000 PTS. 314 58.000

13.2.2 Phase II Site Investigations:

Six Phase I soils were resampled for mercury analyses. Sampling locations are shown on Figure 13-4.

13.3 Analytical Results (See Appendix I, Page 4)

13.3.1 Phase I Analytical Results:

No heavy metals or other contaminants were found at levels significantly different from those detected at the control sites. Traces of mercury (1 to 14 ug/kg) were detected in eleven out of seventeen soil samples (surface and depth samples), but mercury analyses were repeated in Phase II due to questionable calibration data (see Exhibit B). Surface soil collected along transect B for priority pollutant analysis contained 8,292 ug/kg di-n-octyl phthalate and 156 ug/kg N-nitrosodimethylamine (below detection limit). However, the volatile and semi-volatile organics data for Phase I are questionable due to QA/QC deficiencies or unreliable support data (see Exhibit B). The positive detections reported are thus estimated values and some compounds which were not detected may in fact be present. Sample 7A-1 contained manganese at 3,330 mg/kg. Magnesium concentrations ranged from 1,110 mg/kg to 6,540 mg/kg, slightly higher than the concentrations detected at the control sites.

13.3.2 Phase II Analytical Results:

The six samples analyzed for mercury showed concentrations below or near the detection limit (less than 22 to 29 ug/kg).

13.4 Environmental Effects

13.4.1 Qualitative Assessment

This site was chosen for investigation based on its proximity to an explosives manufacturer and reports that barrels of chemicals had been dumped at that location.

However, there was no history of the disposal of wastes other than the accidental chemical spill. Phase I sampling data suggest that phthalates and N-nitrosodimethylamine residues are present. Nitrosoamines levels are approximately one half the levels detected elsewhere at the Refuge where they were evaluated and not considered to represent a concern (see Site 17, Section 24.4), and are similar to the levels detected at the Munitions Control Site. Phthalates are commonly present due to contamination of the QA/QC blanks, and were also detected at the control sites. On this basis, it can be concluded that there is no "source" of waste materials for on-site exposures or for migration to off-site locations.

Because there is no established waste source at this location, it is not possible to have a "complete" exposure scenario. Therefore, on the basis of the information generated, it can be concluded that the site does not represent a risk of chemical exposure to potential human or wildlife receptors.

13.4.2 Quantitative Assessment

Because a complete exposure scenario could not be identified in the qualitative assessment, there is no basis for preparing a quantitative risk evaluation.

13.4.3 Analysis of Uncertainties

The major information relied upon for evaluating this location was the report that barrels of chemicals had been dumped on the site, previous and current manufacture of explosives on and near the site, and site inspection. This suggested that the area could have wastes on it, although the use of the area for waste disposal is not indicated. Chemical residue information consisted of analytical results for surface and depth soil samples. The soils sampled represented the top three feet of surface. Geophysical surveys did not indicate the presence of any buried metallic objects, supporting the analytical results of both Phase I and Phase II. Furthermore, no evidence of explosives residues were detected in soil samples from this site. It can be concluded that the data generated are adequate to support the absence of a waste source when considered in light of the fact that there was no known history of waste disposal at this location. The lack of contaminants detected in the surface or deeper soils suggests that the area does not pose a threat to human health or to the wildlife.

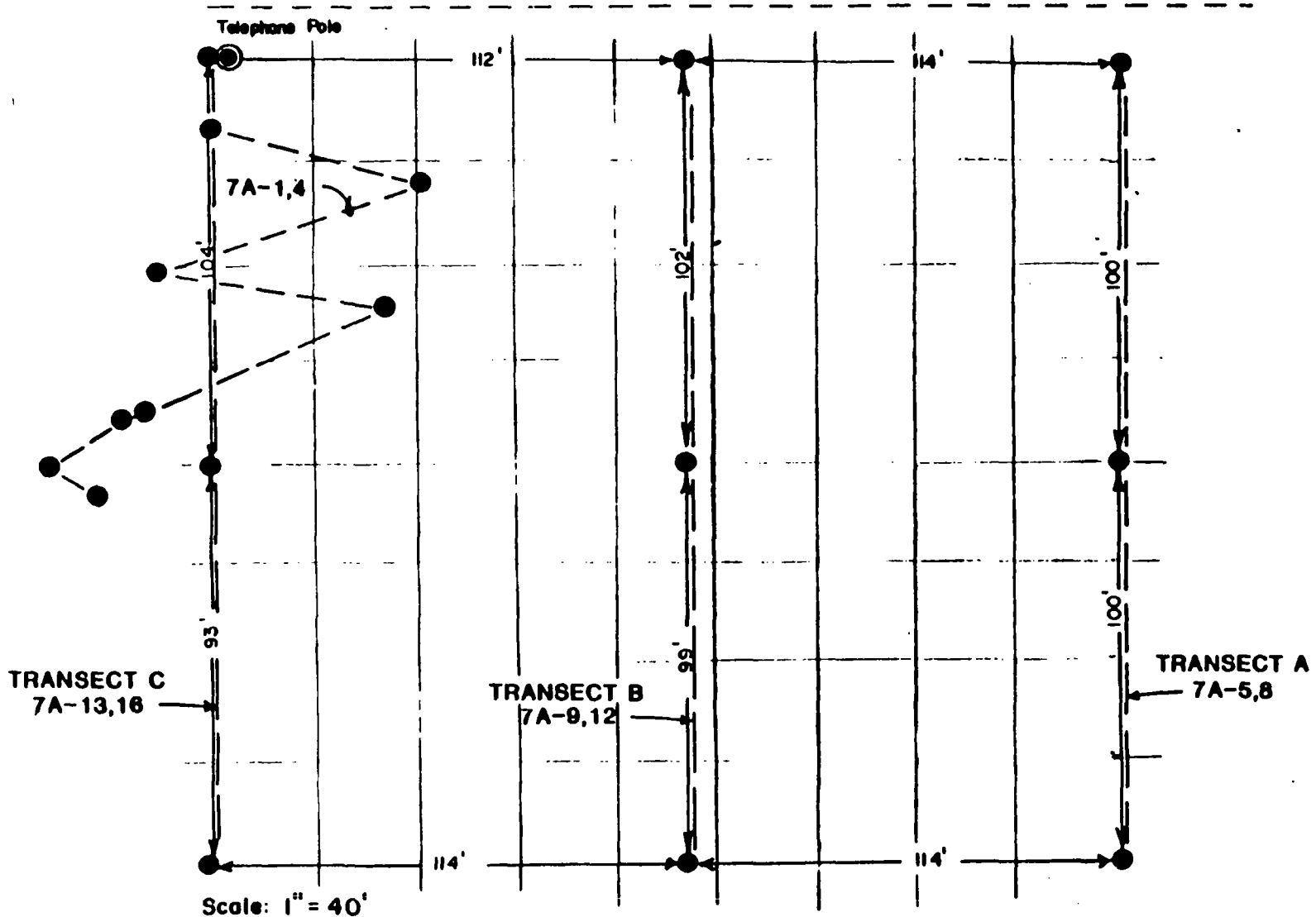
13.5 Preliminary Remedial Alternatives

The analytical results discussed in the previous section indicate that this site does not contain contaminant levels that would result in a negative environmental impact. Therefore there will be no further evaluation of remedial alternatives, and this site will not be included in the FS.

13.6 Conclusions and Recommendations

It can be concluded that the D Area North Lawn site does not represent a chemical exposure risk to human or wildlife receptors at the Refuge or at other locations. No further evaluation is recommended for this site.

SITE 7A **SAMPLING LOCATIONS** **PHASE I** **FENCE LINE**



13.4.3 Analysis of Uncertainties

The major information relied upon for evaluating this location was the report that barrels of chemicals had been dumped on the site, previous and current manufacture of explosives on and near the site, and site inspection. This suggested that the area could have wastes on it, although the use of the area for waste disposal is not indicated. Chemical residue information consisted of analytical results for surface and depth soil samples. The soils sampled represented the top three feet of surface. Geophysical surveys did not indicate the presence of any buried metallic objects, supporting the analytical results of both Phase I and Phase II. Furthermore, no evidence of explosives residues were detected in soil samples from this site. It can be concluded that the data generated are adequate to support the absence of a waste source when considered in light of the fact that there was no known history of waste disposal at this location. The lack of contaminants detected in the surface or deeper soils suggests that the area does not pose a threat to human health or to the wildlife.

13.5 Preliminary Remedial Alternatives

The analytical results discussed in the previous section indicate that this site does not contain contaminant levels that would result in a negative environmental impact. Therefore there will be no further evaluation of remedial alternatives, and this site will not be included in the FS.

13.6 Conclusions and Recommendations

It can be concluded that the D Area North Lawn site does not represent a chemical exposure risk to human or wildlife receptors at the Refuge or at other locations. No further evaluation is recommended for this site.

SECTION 14 - SITE 8, D AREA SOUTHWEST DRAINAGE CHANNEL

14.1 Site Description

Area D is an active Olin operation located north of Crab Orchard Lake. Section 12.1 contains a description of previous activities at Area D.

Site 8 is located within one of the various drainage channels leading from the Olin D Area (See Figure 12-1). These channels discharge to Crab Orchard Lake near the Refuge Waterworks.

14.2 Site Investigations

14.2.1 Phase I Site Investigations:

One composite surface water sample was collected, as well as one composite sediment sample (0-1 ft depth).

14.2.2 Phase II Site Investigations:

No samples were collected in the Phase II study.

14.3 Analytical Results (Appendix I, Page 7)

The water contained TOX concentrations of 28 and 42 (duplicate) ug/L. All other concentrations were below Illinois Public Water Supply Standards except manganese which was 0.16 mg/L versus the standard of 0.15 mg/L, but metals concentrations are only estimated for screening purposes (see Exhibit B). It is noted that the standard for manganese is based on concerns for taste and color in water, and does not represent a threshold for risk to public health or the environment.

No volatile organics were detected. The sediment concentrations were consistent with those detected at the control sites with the exception of magnesium (16,700 mg/kg).

14.4 Environmental Effects

Environmental effects of drainage within the D and P areas are discussed in Section 16.4.

14.5 Preliminary Remedial Alternatives

Preliminary Remedial Alternatives for the D and P areas are discussed in Section 16.5.

14.6 Conclusions and Recommendations

Conclusions and recommendations for the D and P areas are discussed in Section 16.6.

SECTION 15 - SITE 9, P AREA NORTHWEST DRAINAGE CHANNEL

15.1 Site Description

Area P is an active Olin operation located north of Crab Orchard Lake which is used for research and development. The Refuge Manager has indicated that chemicals handled in this area may be non-conventional or "exotic." The site was previously used by Universal Match under contract to the DOD. The Refuge Manager indicated that their operations ceased after a large explosion.

Site 9 is located within one of the various drainage channels leading from the Olin P Area (See Figure 12-1). These channels discharge to Crab Orchard Lake near the Refuge Waterworks.

15.2 Site Investigations

15.2.1 Phase I Site Investigations:

One composite surface water sample and one composite sediment sample (0-1 ft depth) were collected. The sediment was resampled for CLP organics analyses.

15.2.2 Phase II Site Investigations:

Mercury and cyanide analyses were scheduled on sediment resampled from the same location and depth sampled in Phase I.

15.3 Analytical Results (See Appendix I, Page 8)

15.3.1 Phase I Analytical Results:

TOX levels in the water sample were 120 ug/L (180 ug/L duplicate) but no volatile organics were detected. The sediment contained 26 mg/kg

of cyanide and 9 ug/kg mercury, but neither parameter was detected in the water sample. Both cyanide and mercury were scheduled for reanalysis in Phase II.

15.3.2 Phase II Analytical Results:

The sediment resampled in Phase II contained less than 5 mg/kg (wet weight) cyanide. Mercury analyses were not completed due to an oversight in laboratory scheduling.

15.4 Environmental Effects

Environmental effects of drainage within the D and P areas are discussed in Section 16.4.

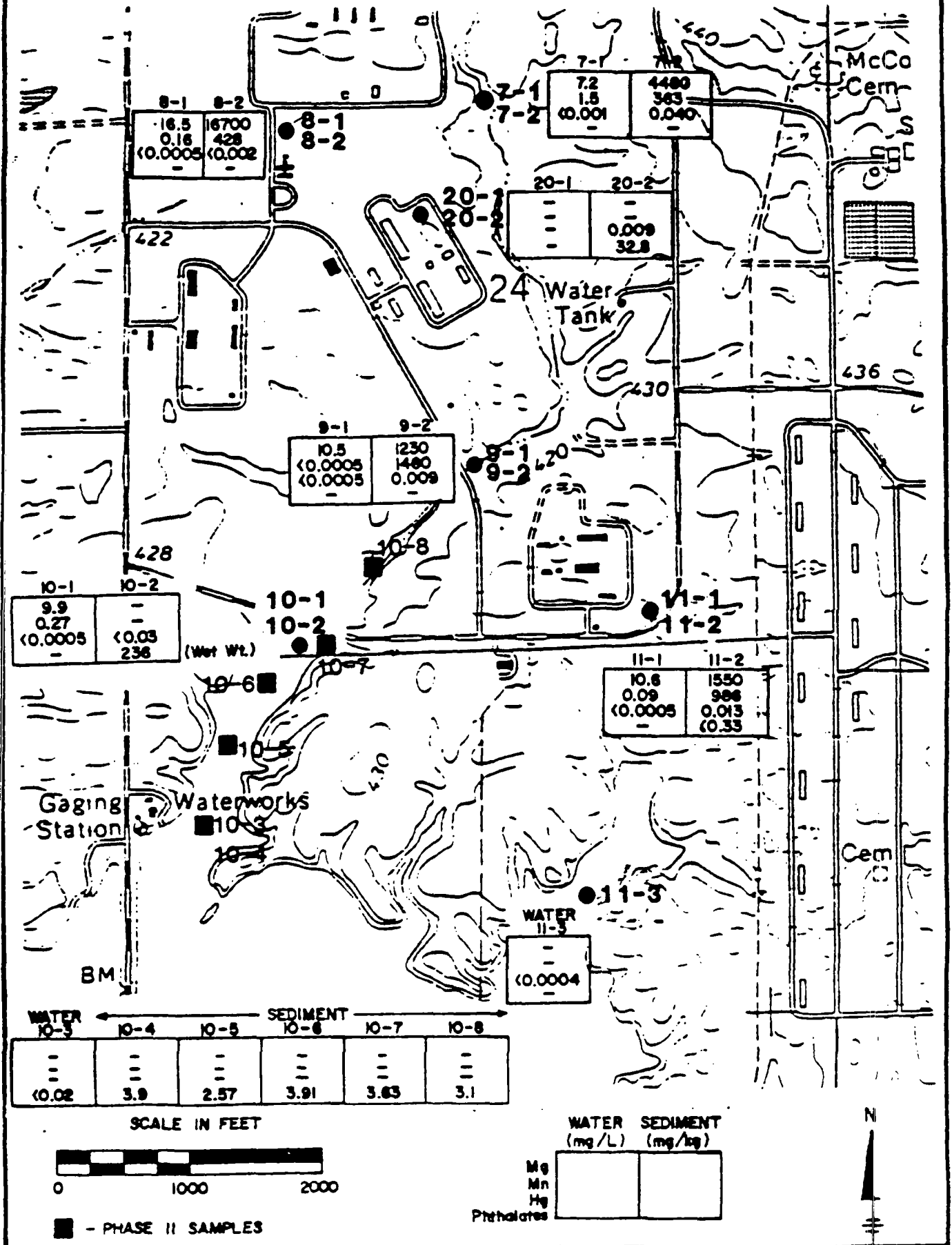
15.5 Preliminary Remedial Alternatives

Preliminary Remedial Alternatives for the D and P areas are discussed in Section 16.5.

15.6 Conclusions and Recommendations

Conclusions and Recommendations for the D and P areas are discussed in Section 16.6.

WATERWORKS SAMPLING LOCATIONS PHASE I & II



SECTION 16 - SITE 10, WATERWORKS NORTH DRAINAGE

16.1 Site Description

Area P is an active Olin operation located north of Crab Orchard Lake. Section 15.1 contains a description of previous activities at Area P.

Site 10 is located within one of the various drainage channels leading from the Olin D and P Areas (See Figure 6-1). These channels discharge to Crab Orchard Lake near the Refuge Waterworks.

16.2 Site Investigations

16.2.1 Phase I Site Investigations:

One composite surface water sample and two composite sediment samples (0-1 ft depth) were collected. The second sediment was a resampling at the same depth and location as the first and was collected for full priority pollutant analysis.

16.2.2 Phase II Site Investigations:

Five grab sediment samples (0-1 ft depth) and one surface water composite were collected from the embayment area and upstream of the bay. The sediments were analyzed for cyanide and base/neutral/acid extractables. Mercury analysis was repeated on one sediment sample from Phase I. The sampling locations are shown on Figure 16-1.

16.3 Analytical Results (See Appendix I, Page 9)

16.3.1 Phase I Analytical Results:

TOX levels in the water sample were 20 ug/L (26 ug/L duplicate) but no volatile organics were detected. Iron (600 ug/L) and manganese (270

ug/L) were above the Drinking Water Standards of 300 and 50 ug/L respectively. Manganese was the only parameter exceeding the Illinois Public Water Standards. Iron and manganese standards are promulgated due to aesthetic concerns of taste and color, thus, the levels present at this site do not constitute a risk to human health. The sediment contained 61 mg/kg of cyanide, 236,000 ug/kg wet weight of di-n-octyl phthalate, and 540 ug/kg wet weight of bis (2-ethylhexyl) phthalate, and 270 ug/kg wet weight N-nitrosodimethylamine. These parameters were not detected in the water sample. Cyanide analyses were repeated in Phase II due to questionable QA/QC data accompanying the Phase I analyses. The reported values for semi-volatiles are estimated only due to deficiencies in the calibration data (see Exhibit B).

16.3.2 Phase II Analytical Results:

None of the five sediments contained detectable cyanide. The sediment reanalyzed for mercury contained less than 30 ug/kg. All sediments, however, contained phthalates in the range of 2250-4800 ug/kg for di-n-butyl phthalate, and from 318-1530 ug/kg bis (2-ethylhexyl) phthalate. Di-n-octyl phthalate was not detected. The water did not contain either cyanide or phthalates.

16.4 Environmental Effects

The Waterworks North Drainage, Site 10, is but one of several portions of a drainage complex emanating from the active Olin Corporation's D and P Areas. These areas are of interest due to their proximity and drainage into Crab Orchard Lake. Other sites, including Sites 7, 8, 9, 10, 11, and 20 as described elsewhere in this report, are very similar to Site 10, but generally

have fewer site contaminants at considerably lower levels. Site 10 is located where these drainage routes coverage prior to entering Crab Orchard Lake; it is also given special emphasis in this analysis because of its closeness to the Refuge Waterworks. For these reasons, the risk assessment for the sites along the waterworks drainage will focus on the exposure potential from Site 10, with abbreviated assessments performed for the other sites, using the same exposure assumptions and scenarios.

16.4.1 Qualitative Assessment

As described above, residues of several site contaminants were detected in the sediments, but not in the water, along some drainage channels associated with the Area P industrial facilities. These included N-nitrosodimethylamine, mercury, di-n-octyl phthalate, di-n-butyl phthalate, and bis-(2-ethylhexyl) phthalate.

Cyanide residues were detected in one sediment sample collected for the Phase I screening analysis but were not validated by the Phase II analyses of cyanide in five sediments. Detected phthalate levels might be attributed in part to contamination of the laboratory QA/QC blanks. Mercury concentrations were similar to those typical for soil matrices (Lindsay, 1979). The detection of N-nitrosodimethylamine in sediment is not considered to pose a risk based on the evaluation of similar concentration levels at Site 17, as well as the limited exposure of sensitive species (e.g.) small wildlife to channel sediments.

Given the nature of the site, the pattern and the magnitude of residues detected, the only potential human receptors identified are facility employees, site intruders, and potentially, consumers of drinking water drawn from Crab Orchard Lake. However, since treatment of the

Refuge water supply includes filtration, any sediment-bound residues should be adequately controlled. No contaminants were detected in the water samples, rendering this transport route non-functional. Since the drainage channels receive intermittent flow and are subject to periodic dry periods, potential wildlife exposures will be limited to acute exposures. However, the levels of residues detected in site sediments are not considered acute toxins and do not present a concern for toxicity via acute exposure to humans or terrestrial animals. In view of the lack of detectable residues in water, and the low levels in sediment, exposures to aquatic benthic and non-benthic organisms will not be significant.

Because there is no waste 'source' at this site, and the potential for exposure is unlikely or, at worst, of short duration so that the levels detected would not represent a risk, a complete exposure pathway is not possible.

16.4.2 Quantitative Risk Assessment

Due to the lack of a complete exposure scenario for this site, there is no basis for preparing a quantitative assessment.

16.4.3 Analysis of Uncertainties

The major areas of uncertainty in this analysis include:

1. The possibility exists that low level residues in sediments may reach Crab Orchard Lake, expanding the exposed populations. Potential exposure routes include particulates transported by surface water runoff, and solubilization of contaminants and transport by surface water.

2. The detection of cyanide in one sediment in Phase I was invalidated by the absence of cyanide in five Phase II sediment samples, thus introducing uncertainty due to the quality of the laboratory data.
3. The ability of soil-bound phthalates to produce toxicity in benthic organisms in the drainage channels is unknown. The actual levels of phthalates present is uncertain because of the interference of lab contaminants in the QA/QC blank.

16.4.4 Risk Assessments for Other Drainage Sites

a) Site 7-D Area Southeast Drainage Channel

Contaminant: 300 ug/kg mercury in sediment (Phase II reanalysis)

Exposure Rate-Human: 0.0002 ug/kg

Mouse: 0.02 mg/kg

Benthic Invertebrate: Indeterminant

Risk Assessment-Human: Exposure estimate for acute exposure is 1000-fold lower than chronic acceptable daily intake of 0.2 ug/L.

Mouse: Exposure estimate is 100-fold lower than a lowest observed effect level in a chronic rat bioassay. Benthic Invertebrate: Chronic exposure to mercury may have adverse effects on benthic communities.

b) Site 8-D Area Southwest Drainage Channel

Contaminant: 16700 mg/kg magnesium in sediment (Phase I screening result).

Risk Assessment: Magnesium is not regarded as a toxicant in either humans or wildlife. Since a source of toxicant is not established at this site, risk cannot be assessed.

c) Site 9-P Area Northwest Drainage Channel

Contaminant: 26 mg/kg cyanide in sediment.

Risk Assessment: Referring to the rationale developed in the qualitative assessment for Site 10, the frequency of exposure, applicable transport routes, and potential receptor populations are not at risk via acute exposure at the levels of cyanide detected at this site. Based on the available data, the cyanide residues in sediments appear to be in the form of the less toxic salts, since most of the highly toxic cyanide forms are also highly soluble and would be expected to be detected in the water column samples.

d) Site 11-P Area Southeast Drainage Channel

Contaminants: 51 ug/kg mercury in sediment (Phase II reanalysis), 31 ug/kg chloroform in water.

Risk Assessment: Using a similar assessment as for the mercury residues at Site 7, humans would not be at risk from exposures at this site. Residues of mercury at this site may be sufficiently low to constitute a minimal risk to small vertebrates.

The concentrations of chloroform (31 ug/L) and bromodichloromethane (3 ug/L) in water at Site 11 are well below the Drinking Water Standard of 100 ug/L for total trihalomethane compounds as well as below the AWQC for chloroform for protection of aquatic life. Site concentrations of chloroform were above the AWQC criteria for protection of human health (0.19 ug/L), however. These constituents were either undetected (bromodichloromethane) or found at very low concentrations in sediments (6 ug/kg chloroform) from the same site, and were undetected at other sites along the Waterworks drainage route. The levels detected in water samples are thus not felt to represent a concern to the environment or to

human or animal species. On this basis, these compounds are not considered to be site indicator contaminants, and a quantitative risk assessment is not justified.

e) Site 20-D Area South Drainage Channel

Contaminants: 30500 ug/kg di-n-octyl phthalate

2320 ug/kg di-2-ethylhexyl phthalate

336 ug/kg N-nitrosodimethylamine in sediment

(Phase I screening analyses).

Risk Assessment: The toxicity of N-nitrosodimethylamine levels in soil at roughly four times the concentration detected at this site are evaluated in Section 26.4 (Site 19). The exposure level associated with the detected N-nitro- sodimethylamine concentration in sediment (336 ug/kg), considered as twice this concentration due to deficiencies noted in the Phase I data analyses, is estimated at 0.0045 mg/kg/day, a level four-fold lower than the lowest observed effect level for the most sensitive species. Based on the limited exposure of sensitive receptors to channel sediments, the lower level of acute toxicity associated with lower levels of residues, and the remote potential for chronic exposures at this site, nitrosoamines will not be considered further in this assessment. The phthalate compounds detected (di-n-octyl and di-ethylhexyl phthalates) are not acutely toxic, and, using the same reasoning as above, any potential for chronic effects in humans is negated by the short term nature of the worst case exposures. There are insufficient data to estimate the chronic effects of sediment-bound phthalates to small vertebrates and invertebrates, and no residues were detected in the water column. The general ability of this class of chemicals to impair

reproduction and produce other effects may be a cause for concern at this site, if it were demonstrated that chronic exposure scenarios were probable. Di-n-octylphthalate was also detected at the control sites, and may have been present as a lab contaminant.

16.5 Preliminary Remedial Alternatives

The critical parameters for the sites within the industrial D and P areas (Sites 7-11, and 20) include cyanide, iron, magnesium, manganese, mercury, and phthalates. Manganese and iron concentrations in water were above the Illinois Public Water Supply Standards and Federal MCLs, but these concentrations were estimated due to unreliable QA/QC support data and were not considered to represent any health risk at the levels present. Site 11 surface water contained traces of chloroform above the AWQC for human health, but below the same criteria for aquatic life protection. Phthalates were detected in several of the sediment samples, but at levels which were not vastly different from other sites at the Refuge or from Refuge background.

A preliminary evaluation of applicable remedial measures for the Waterworks tributaries might justify monitoring of the surface waters for cyanide, iron, magnesium, manganese, mercury, and phthalates. Attachment 1 includes a proposed monitoring plan to address follow-up studies for the Waterworks Drainage Sites.

16.6 Conclusions and Recommendations

It can be concluded that the Waterworks Drainage sites do not contain contaminants at levels that would pose a risk to aquatic organisms, wildlife, or human receptors. Due to continuing industrial activities in the area, it is recommended that follow-up monitoring for parameters including iron,

magnesium, manganese, cyanide, and phthalate esters in water be initiated and continued past the RI/FS Investigations. (See Attachment 1). These sites will not be considered in the FS.

SECTION 17 - SITE 11, P AREA SOUTHEAST DRAINAGE CHANNEL

17.1 Site Description

Area P is an active Olin operation located north of Crab Orchard Lake. Section 15.1 contains a description of previous activities at Area P.

Site 11 is located within one of the various drainage channels leading from the Olin P Area (See Figure 12-1). These channels discharge to Crab Orchard Lake near the Refuge Waterworks.

17.2 Site Investigations

17.2.1 Phase I Site Investigations:

One composite surface water sample and two composite sediment samples (0-1 ft depth) were collected. The second sediment constituted a resampling at the same depth and location for full priority pollutant analysis.

17.2.2 Phase II Site Investigations:

One Phase I surface water (grab sample) was resampled for mercury and cyanide analyses, while one sediment sample was resampled for mercury analysis. This sampling location is shown on Figure 16-1.

17.3 Analytical Results (See Appendix I, Page 10)

17.3.1 Phase I Analytical Results:

The water sample contained TOX levels of 200 ug/L (270 ug/L duplicate), bromodichloromethane (3 ug/L), chloroform (31 ug/L) and the explosive residue HMX at 8 ug/L. No other explosive residues or organic compounds were detected. Chloroform levels exceeded the AWQC for

human health in water but were well below the criteria for protection of aquatic life. Manganese was detected at 90 ug/L which is above the Federal MCL of 50 ug/L but below the Illinois water standards; this level is not considered to pose any concerns for health protection. All other detectable concentrations in water were within Illinois Public Water Supply Standards and Federal Drinking Water Standards. Metals concentrations were estimated for screening purposes only. Acetone (252 ug/kg wet wt) and methylene chloride (47 ug/kg wet wt) were detected in the sediment sample 11-2, but these were also detected in the QA/QC blanks. The sediment also contained 63 ug/kg N-nitrosodimethylamine, 14 ug/kg 1,1-dichloroethene (wet wt) and several other volatile organics quantified below the detection limit. The volatile and semi-volatile organics data for Phase I are questionable due to QA/QC deficiencies or unreliable support data. (See Exhibit B). The positive detections reported are thus estimated values and some compounds which were not detected may in fact be present. All other sediment concentrations were similar to soil concentrations detected at the control sites, except mercury (13 ug/kg). Mercury analysis was repeated in Phase II due to questionable calibration data.

17.3.2 Phase II Analytical Results:

Neither cyanide nor mercury were detected in the Phase II water sample. The Phase II sediment sample contained mercury at 51 ug/kg.

17.4 Environmental Effects

Environmental effects of drainage within the D and P areas are discussed in Section 16.4.

17.5 Preliminary Remedial Alternatives

Preliminary Remedial Alternatives for the D and P areas are discussed in Section 16.5.

17.6 Conclusions and Recommendations

Conclusions and Recommendations for the D and P areas are discussed in Section 16.6.

SECTION 18 - SITE 11A, P AREA NORTH

18.1 Site Description

Located outside of the fence north of the Olin P Area is Site 11A, consisting of abandoned L-shaped covered walkways approximately 100 feet and 85 feet long which terminate at loading areas (See Figure 18-1). The central structure contains a loading dock and a steamhouse containing a concrete pit with about 5 feet of clear standing water. An old roadbed runs west and north of the structure and draining swales surround all of the buildings. An abandoned sewer line also runs across the north edge of the site. It has been reported that contaminants were dumped on the ground outside of the building.

18.2 Phase I Site Investigations

18.2.1 Phase I Site Investigations:

Eight soil and sediment composites (0-1 ft depth) were collected. One soil (location 11A-3) was resampled and analyzed for the full CLP analyses.

18.2.2 Phase II Site Investigations:

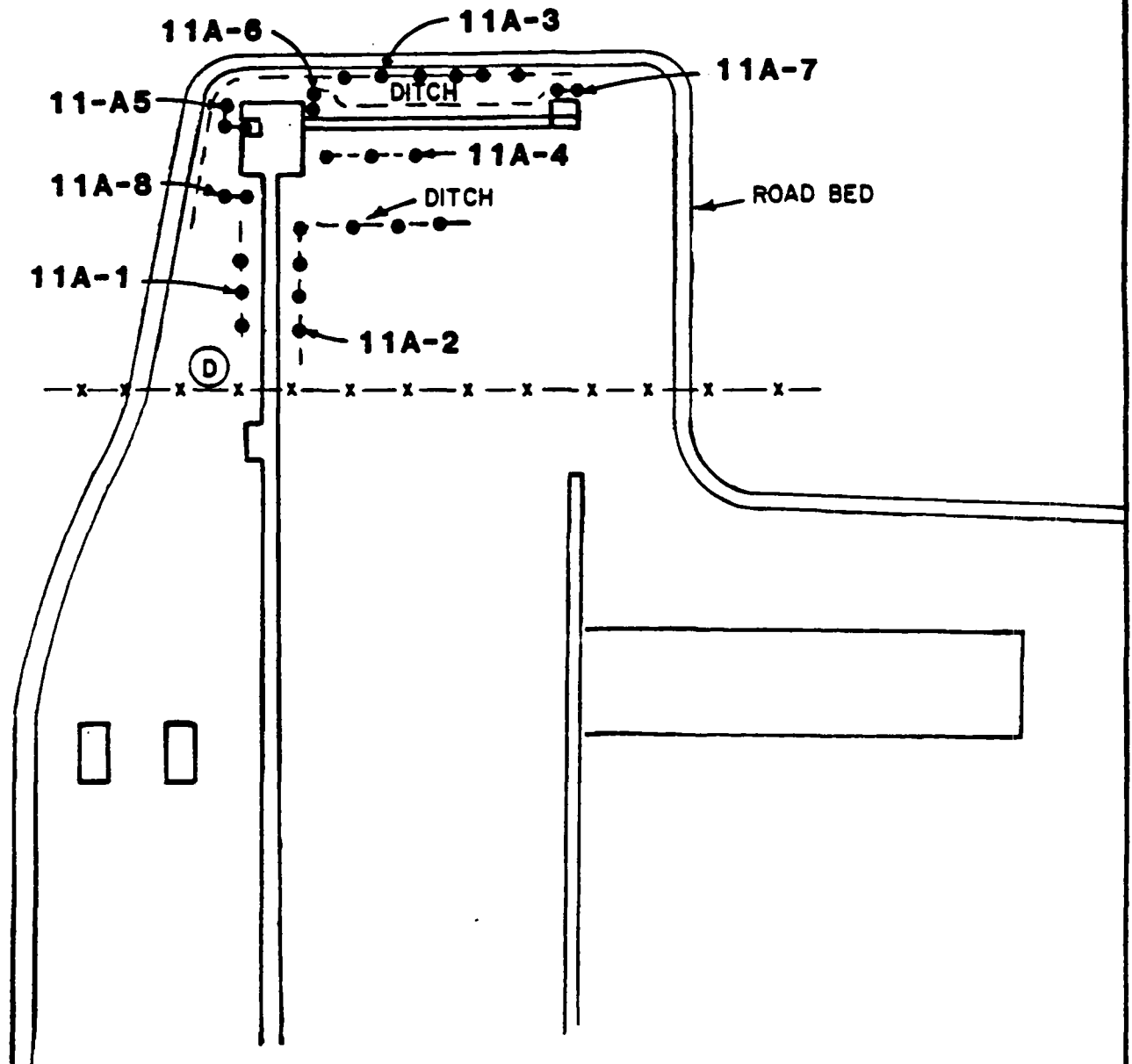
One of the Phase I composite samples (11A-5) was resampled for mercury.

18.3 Analytical Results (See Appendix I, page 5).

18.3.1 Phase I Analytical Results:

Magnesium concentrations ranging from 15,100 to 29,900 mg/kg were found in soils outside three doorways. The magnesium level in drainage

**SITE IIA
P AREA NORTH
PHASE I**



APPROXIMATE SCALE



ⓓ - DECONTAMINATION AREA

ditches was generally an order of magnitude lower than the levels detected in samples collected near the doorway, and similar to those concentrations detected at the control sites. Lead concentrations of 130 mg/kg were detected in two soil samples from the north walkway; all other soils contained lead levels within the ranges detected at the control sites. The metals concentrations are reported as estimated values. Two sediments (11A-3 and 11A-4) contained low concentrations of PCBs 0.6 and 0.2 mg/kg wet weight (0.9 and 0.3 mg/kg dry weight). One sediment was resampled for full analysis after initial FID screening showed 15,568 ug/kg. The sample contained 1,106 ug/kg di-n-octylphthalate, and 262 ug/kg N-nitrosodimethylamine; however, these levels are estimated due to QA/QC deficiencies in the analyses of semi-volatiles (see Exhibit B).

18.3.2 Phase II Analytical Results:

The mercury concentration in the soil sample was 43 ug/kg. No mercury had been detected in the Phase I analyses.

18.4 Environmental Effects

18.4.1 Qualitative Assessment

This site was chosen for investigation based on reports that contaminants had been dumped on the ground outside of the building, possibly contaminating the surrounding soil and sediment. A concrete pit containing standing water, drainage swales, and an abandoned sewer line were viable transport mechanisms for contaminated waste, if present.

The Phase I sampling data indicate that the magnesium concentrations detected were slightly higher than Refuge background levels, yet were

not high enough to pose a risk to human health or to the environment. Traces of lead and di-n-octyl phthalate were also detected but were below their respective background concentrations. Mercury levels detected in the Phase II sample were above the levels found at the control sites but were within the range which would be considered common in soil matrices (Lindsay, 1979). The detected level of 194 ug/kg N-nitrosodimethylamine is similar to the levels evaluated at Site 17 (Section 24.4) where this contaminant was not considered to represent unacceptable risk levels to humans or wildlife.

Since there is not a "true" waste source at this location, a "complete" exposure pathway is not possible; it can thus be concluded that the site does not represent a risk of chemical exposure to potential human or wildlife receptors.

18.4.2 Quantitative Assessment

Because a complete exposure scenario could not be identified in the qualitative assessment, there is no basis for preparing a quantitative risk evaluation.

18.4.3 Analysis of Uncertainties

The major pieces of information relied upon for evaluating this location were the verbal accounts of activities on the site, site inspection, and sample analyses, all of which suggested the area could have wastes on it. An inspection of the site revealed a number of viable transport mechanisms through which a potential receptor might receive exposure to the waste source, if any.

Chemical residue information was obtained only for the top one foot of soil; deeper soil borings and ground water monitoring were not conducted. Since contamination of the site occurred reportedly through surface dumping of waste materials, soil contamination is most likely to be found at the surface. Since there is no evidence to suggest that the surrounding soil has been disturbed, these samples should adequately represent the conditions of the site.

The concentrations of lead and di-n-octyl phthalate detected in the soil samples are comparable to those detected at the control sites. The mercury concentrations are not considered to warrant further remedial action. Likewise, the magnesium concentrations are not considered to represent a concern or risk of exposure.

It can be concluded that the data generated are adequate for evaluation of the remedial alternatives for this site. The sampling data suggest that the soil is not contaminated with harmful concentrations of waste and therefore does not threaten to contaminate the groundwater or surface water in the vicinity.

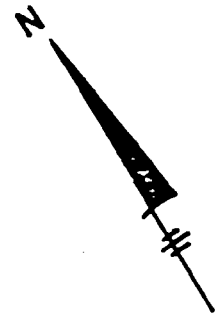
18.5 Preliminary Remedial Alternatives

The analytical results discussed in the previous section indicate that this site does not contain contaminant levels that would result in a negative environmental impact. Therefore there will be no further evaluation of remedial alternatives, and this site will not be included in the FS.

18.6 Conclusions and Recommendations

It can be concluded that the P Area North site does not represent a chemical exposure risk to human or wildlife receptors at the Refuge or at other locations. No further evaluation is recommended for this site.

**SITE 12
AREA 14 IMPOUNDMENT
PHASE I**

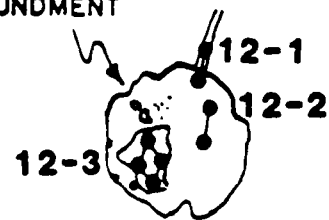


BUILDINGS

(D)

**PARKING
AREA**

**ABANDONED
IMPOUNDMENT**



APPROXIMATE SCALE



(D) - DECONTAMINATION AREA